9.17 AMPS Noise Floor Study

AMPS Noise Floor Study

Sean Haynberg
Director of RF Technologies

David Stern
Vice President

Dominic Villecco
President

March 21, 2002

AMPS Noise Floor Study

TABLE OF CONTENTS:

1. Executive Summary 1

2. Introduction 2

3. Test Overview 3

3.1. Overview of Test Equipment 5
3.2. Signal Level Reference Points 6
3.3. Cell Site Selection 7

4. Test Procedures 11

4.1. Test Coordination 11
4.2. Test Procedures 11

5. Test Results 14

6. Analysis of Test Results and Noise Floor Issues 19

6.1. Cell Site Operating Noise Floor in Today's Cellular Networks 19
6.2. Other Technology and Cell Site Equipment 20
6.3. Cell Site Equipment System Noise Floor 21

7. Conclusion 24

8. Appendix 25

8.1 Pictures of Test Setup 25
8.2 PLM Graphs of Cell Sites 27

1. Executive Summary

The Advanced Mobile Phone System (AMPS) Noise Floor Study was performed in Verizon Wireless' cellular network within the surrounding Philadelphia, PA and New Jersey market area. A total of eighteen cell sites are included in the study. The cell sites are representative of normal sites within today's cellular markets types and signal levels. These sites are classified into four market type categories: Dense Urban, Urban, Suburban, and Rural.

The objective of the study is to provide *actual* field measurements of typical operating noise floor levels, as observed by the cell sites in two ways:
1. The distribution of operating noise floor measurements over a 24-hour period.
2. The operating noise floor level observed during day-time field tests.

The results of the 24-hour noise floor measurements, for the 18 cell sites, range from –119 dBm to –127 dBm, with an average of –126 dBm. Based on these results, "toll quality" AMPS calls can maintain service on these cell sites at very low levels. The minimum "toll quality" call signal level with 17 dB C/I, is –102 to –110 dBm, with an average of –109 dBm. The results of the day-time noise floor field tests range from –118 dBm to –128 dBm, with an average of –125 dBm.

The results of the AMPS Noise Floor Study show the low noise floor levels present in today's cellular networks. These levels are lower than systems have been in the past, due to trends in cellular system usage and cellular system design, which are further explained in section 6.1 of this report.

Based on the results of this study, the operating noise floor level for AMPS cellular systems is represented by –123 dBm for Dense Urban markets, –126 dBm for Urban markets, and –127 dBm for Suburban and Rural markets. These levels represent the operating noise floor for the 18 cell sites, averaged by market type and measured over a 24-hour period for a typical business day.

The results of this study are representative of AMPS cellular systems using typical cell site equipment. Cell sites using other equipment or technology, such as tower-top LNA, superconductor or smart antenna systems as described in section 6.2, offer cell site operating noise floor levels that are lower than the levels provided in this report.

2. Introduction

The purpose of this testing is to provide *actual* field measurements of typical operating cell site noise floor levels. This "operating noise floor" level is to include the thermal noise, ambient environment noise, co-channel and adjacent channel noise floor level, as observed by the cell site receiver. This is the operating noise floor level that is addressed by this noise floor study and report.

The cell sites included in this study are representative of normal sites within today's cellular market types and signal levels. A total of eighteen cell sites are included in the study. These sites are selected as representative sites within Verizon's Cellular B-side market within the surrounding Philadelphia, PA and New Jersey market area. These sites are classified into four market type categories: Dense Urban, Urban, Suburban, and Rural.

The wireless technology that is included in this testing is the Advanced Mobile Phone System (AMPS), as defined by the IS-553 wireless standard. The cell site equipment utilized by Verizon Wireless in this market is the Lucent Series 2 model. This cell site equipment type is very common for cellular sites, and its configuration and performance meet the industry standards for operation. (Digital wireless technologies are not included in this testing. The digital wireless technologies CDMA (IS-95), 3G-1xRTT, and TDMA are currently in operation within this cellular market.)

V-COMM developed the test plan, test methods, and test procedures to accomplish this AMPS Noise Floor Study. All field tests are performed at cell sites within Verizon's market. V-COMM coordinated test activities, reporting requirements, and cell site information with Verizon's regional performance and operations staff to accomplish this testing.

V-COMM is an independent wireless telecommunications engineering firm. Our team represents over 50 years of in-depth engineering experience in wireless telecommunications. We have provided our expertise to wireless operators in engineering, system design, implementation, expansion, system performance, optimization, and new technology evaluation. We have direct experience in all wireless technologies.

The test overview, procedures, results, analyses, and conclusions are provided in the following sections of this report.

3. Test Overview

The objective of this testing is to provide *actual* field measurements of typical operating noise floor levels, as observed by the cell site receiver. All test plans, methods, and procedures were developed with this objective.

To achieve this objective, the operating noise floor must be measured with the cell site's receiver performing the measurements. This will ensure the characteristics of the receiver under test matches the one performing the measurements. Using other receivers or test equipment to measure the noise floor can lead to different results, since their receiver characteristics may not match the cell site's receiver. For example, if a spectrum analyzer or receiver test equipment is used to measure the noise floor it may be more sensitive and utilize narrower resolution and intermediate frequency (IF) bandwidths than a typical cell site receiver. For this reason, the cell site receiver is utilized in this testing to measure the operating noise floor level of the cell site.

The cell site equipment type in this market is Lucent Series 2 model. The Lucent equipment has the ability to perform cell site receive measurements with the Power Level Measurement (PLM) function. For this study, the PLM is used to measure the distribution of operating noise floor levels over a 24-hour business day period, as observed by the cell site receiver. The PLM uses the receiver in the radio control frame (RCF) to perform the measurements. With Lucent's 15 dB receive path gain offset to the radio, all measurements will be referenced to the input of the cell site. The PLM Mode 2 function provides measurements of the operating noise floor level on an idle AMPS channel and records signal levels into 3.125 dB bins. With this resolution, the measured data is within +/- 1.562 dB of the center of the bin. The signal level of each bin is referenced at the center value. The accuracy of the receiver measurements is given by Lucent as approximately +/- 1 dB. To confirm this level of accuracy, tests are performed in the field at the 18 cell sites with calibrated test equipment. The PLM 50% threshold is provided in Table 5.1, as the median operating noise floor for the cell site, over the 24-hour period.

The following field tests are performed at the 18 cell sites:

Field Test #1
Verify the accuracy of the measurements reported by the cell site radio, using a calibrated signal generator connected to the cell site receive system. Include levels within the dynamic range of the receiver and to the lowest signal level that can maintain a call on the cell site, without muting the receiver. This level is approximately to 2 dB above the noise floor. The purpose of this test is to confirm the accuracy of the measurements provided by the 24-hour PLM data.

Field Test #2
Using a calibrated signal generator connected to the cell site receive system, observe the lowest signal level that can maintain an AMPS call on the cell site, with no audio

muting. At this level, the call is maintained with the cell site receiver decoding SAT correctly and continuously, without interruption and without muting the receiver. At this level, the signal-to-operating-noise-floor level (S/N) is estimated to 2 dB. If the signal is decreased below this level, the cell receiver will begin to lose the ability to decode the 6 kHz SAT (Standard Audio Tone - used to maintain calls), and will begin to mute the audio tone. Typically, 1 dB below this no muting test call signal level, the audio begins to mute approximately 5-10% of the time; 2 dB below this level the audio mutes approximately 50-60% of the time; and the call drops when the SAT Fade Timer is expired (typically 10 seconds). During this call test in the field, V-COMM estimates the cell site's operating noise floor is 2 dB below this no muting call signal level. The purpose of this test is to establish lowest signal level that can maintain an AMPS call on the cell site, with no audio muting. From this level, we are able to estimate the cell site's operating noise floor level, during the day-time field tests between 9:00 am and 3:00 pm.

<u>Field Test #3</u>
Using a spectrum analyzer connected to the cell site receive system, after the 45 dB preamplifier, record a snapshot of the average noise floor level observed. This is the operating noise floor level of the spectrum analyzer, which is generally lower than the cell site receiver, since the resolution bandwidth is narrower. The purpose of this test is to support the estimated field test operating noise floor level, for the cell sites with noise floors above the equipment's system noise floor.

In field tests #1 and #2, the signal generator is connected to the –50 dB port of the 1st direction coupler in the cell site's receive system, within the antenna interface frame (AIF). The measured offset from this coupler port to the input of the cell site, and the test cable loss, are used to reference all signal levels to the input of the cell site. The results of field test #1 indicate the accuracy of the measurements recorded by the cell site receiver are within Lucent's +/- 1 dB threshold, for 12 of the 18 sites tested. For 6 of the 18 sites, the test results indicate an offset is required to bring their accuracy in accordance with this +/- 1 dB threshold. (These six receivers, site # 5-8, 11 and 16, measure almost 3 dB lower than the calibrated signal reference levels, and therefore their PLM data provided in this report, is increased by this 3 dB offset, to bring their accuracy in-line with the other receivers.)

In field test #3, the spectrum analyzer is connected to the output of the 1 to 9 splitter at the top of the radio channel frame (RCF) in the cell site receive system. The measured offset from this port to the input of the cell site, and the attenuation of the test cable, is used to reference all signal levels to the input of the cell site. These readings were generally lower than the PLM measurements by a few dB, since the resolution bandwidth of the analyzer was narrower than the cell site receiver's bandwidth. For sites with the highest operating noise floors, the analyzer's measurements yielded similar results. For example, the analyzer measured the average noise floor of the Dense Urban Cell 85 to –119 dBm, which has a –118.5 dBm for the 50% PLM value and –118 dBm for the "Estimated Noise Floor During Test" value.

All field tests and PLM measurements are performed under normal cell site and antenna system configuration. No changes were made to the cell site or antenna systems to perform these tests. Both receive diversity systems remain connected to the antennas during all tests.

The test results of the PLM and field tests are provided in "Test Results" section of this report. The operating noise floor of the 18 sites are provided in two ways:

1. The distribution of operating noise floor measurements taken by the 24-hour PLM.
2. The operating noise floor observed during field testing, as estimated by the minimum call level that can maintain an AMPS call with no SAT muting.

Section 4 of this report provides the test procedures in more detail.

3.1. Overview of Test Equipment

This section lists the test equipment that was utilized during this AMPS noise floor testing. The test equipment was checked and verified before using in the field. The HP 8921A test equipment was within its current calibration period; it was calibrated within the prior 12-month period. The test cables and cell site offsets reference to the cell site input port were measured and recorded during testing.

Test Equipment:

1. HP 8921A Communications Test Set -- Signal Generator / Spectrum Analyzer
2. Lucent Power Level Measurements (PLMs)
3. Lucent RF Call Trace
4. Nokia 2160 cellular telephone, in AMPS mode
5. Landline telephone
6. Miscellaneous test cables, connectors, and hardware.

Two functions of the HP 8921A test set were utilized. The signal generator function was used for field tests #1 and 2 to inject a signal into the cell site receive system and maintain an AMPS call for the duration of the test. The spectrum analyzer function was used for field test # 3 to record a snapshot of the average operating noise floor level observed for the AMPS channel and receiver utilized in field tests #1 and #2, during the test period. The test period was approximately 1 ½ hour per cell site, during the day-time weekday hours between 9:00 am and 3:00 pm. The signal level accuracy of the calibrated HP 8921A Signal Generator, is specified by HP as within +/- 1 dB. V-COMM checked the signal accuracy with another calibrated spectrum analyzer (HP 8591) for various frequencies and signal levels across the cellular band, and observed the HP 8921A signal level was within 0.2 dB of the HP 8591.

The Lucent Power Level Measurement (PLM) Mode 2 function was used to measure and record the operating noise floor over a 24-hour period, as observed by the cell site receiver, on the specific site/sector/channel that was seized during the field testing. The resolution of the Lucent PLM measurements is approximately 3 dB, since it uses 3.125 dB bin sizes. The center value of the bin is the reference value for the bin, and represents data collected within +/-1.562 dB of the center value of the bin.

The Lucent RF Call Trace was used in field tests #1 and #2, to record the cell site receive signals of the AMPS call that was maintained during the testing, as measured by the cell site receiver. Lucent's receive path gain of 15 dB, allows these measurements to be referenced to the cell site input, and is compared to the injected calibrated signal levels to verify the accuracy of the measurements reported by the AMPS receiver. The resolution of the Lucent RF Trace measurements is reported in 1 dB increments.

Lucent's RF Trace and PLM Mode 2 records the cell site receive signal levels with the cell site's voice channel radio receiver. The accuracy of the cell site receiver measurements is approximately +/- 1 dB, as provided by Lucent.

A Nokia 2160 cell phone was used to initiate the AMPS test call to a landline telephone. The signal generator was used to seize and maintain the call using a modulated carrier with a 1 kHz tone (2.9 kHz deviation) and a 6 kHz SAT (2 kHz deviation) to represent typical cellular AMPS voice channel characteristics.

The cell site landline telephone was used to receive and maintain the AMPS cellular telephone call for the duration of the test. The engineer used the landline telephone to monitor the audio tone of the AMPS telephone call throughout the test.

Miscellaneous test cables, connectors, and hardware were used to connect the HP8921A to the cell site equipment.

3.2. Signal Level Reference Points

All signal levels that are listed in this report are referenced to the input to the cell site. Lucent references this as the J1 port. This reference is the antenna side connector of the very first element in the cell site receive system; which is the same reference as the equipment side of the antenna jumper cable, that connects to the transmission line. All signal level units are in dBm (decibels, relative to 1 milliwatt).

All measurements performed by the cell site receiver are offset by Lucent's receive path gain (15 dB for Series 2 cell sites), to reference the input of the cell site. Lucent's RF Trace and PLM measurements are performed by the AMPS radio receiver and use this offset to reference the input of the cell site. During field tests #1 and #2, the signal generator injected calibrated signal levels into the cell site receive system, at the –50 dB coupler port. For these tests, an offset was used to reference the input of the cell site, which takes into account the loss in the test cable and the path offset to the J1 port.

During field test #3, the spectrum analyzer measured the average operating noise floor of the cell site from the output of the 1 to 9 splitter, at the top of the radio channel frame (RCF). The receive path offset was measured to this point, to reference the level measured to the input of the cell site.

3.3. Cell Site Selection

The cell sites included in this AMPS Noise Floor Study were selected to be representative of normal sites within today's markets types, and to exhibit typical operating signal and noise floor characteristics. A total of eighteen cell sites are included in the study. The sites are located within the surrounding Philadelphia, PA and central New Jersey market areas.

The 18 sites are classified into 4 market type categories: Dense Urban, Urban, Suburban and Rural. V-COMM selected these sites after reviewing over 200 sites within Verizon's local market area to determine the sites that would be representative of normal sites with typical surrounding signal and noise floor levels, antenna elevations, and antenna configurations, for each market category. In this market, Verizon's cell sites are 3-sectored sites, which is the most common antenna site configuration for cellular systems. The cell site antenna orientation is north, southeast, and southwest, for sectors alpha, beta, and gamma (A, B, G) respectively.

Cell site information for the 18 cell sites is provided in the table below. This information includes the site #, market type, cell ID, sector tested, location, cell type, ground elevation, antenna height elevation, antenna type, and antenna down-tilt.

Table 3.1 Cell Site List

The table below contains the data pertaining to the configuration, cell site type, location and antenna system information, for the 18 cell sites that were included in this AMPS Noise Floor Study

Site	Classification	ECP	CELL	Sector Tested	County, State	GE (ft)	ANT TIP HT (ft)	Antenna Type	Downtilt (degrees)
1	Dense Urban	5	54	Alpha	Center City, Philadelphia, PA	40	180	EMS-FV901210	10
2	Dense Urban	5	58	Gamma	Center City, Philadelphia, PA	40	110	ALP-9012-DIN	8
3	Dense Urban	5	85	Gamma	Center City, Philadelphia, PA	21	156	ALP-6014-N	10
4	Urban	5	80	Gamma	Philadelphia, PA	80	150	SCP-9012	0
5	Urban	5	63	Gamma	Philadelphia, PA	80	75	ALP-6014-N	8
6	Urban	5	65	Gamma	Philadelphia, PA	28	100	ALP-6014-N	5
7	Urban	5	78	Alpha	Philadelphia, PA	80	155	ALP-8013-DIN	4
8	Urban	5	57	Alpha	Philadelphia, PA	19	75	ALP-11011-N	0
9	Suburban	2	87	Beta	Gloucester, NJ	35	157	ALP-8013-N	0
10	Suburban	2	106	Beta	Camden, NJ	70	110	ALP-8013-DIN	2
11	Suburban	7	70	Alpha	Bucks, PA	283	140	ALP-9212-DIN	0
12	Suburban	8	66	Gamma	Delaware, PA	292	125	ALP-6014-N	4
13	Suburban	5	79	Alpha	Delaware, PA	365	130	ALP-8013-N	5
14	Rural	6	52	Beta	Cumberland, NJ	104	110	SCP-9012	0
15	Rural	7	50	Gamma	Montgomery, PA	239	118	ALP-8013-DIN	0
16	Rural	7	42	Gamma	Lehigh, PA	630	182	ALP-8013-DIN	0
17	Rural	7	53	Gamma	Montgomery, PA	388	200	ALP-9212-DIN	0
18	Rural	7	102	Alpha	Bucks, PA	331	136	ALP-8013-DIN	0

Notes
1. The Dense Urban sites are in "Center City", within the Philadelphia county.
2. Cell Type is a standard Lucent Series 2 cell site, the classic version (not the Series 2m or 2mm).
3. GE - Ground elevation, above mean sea level.
4. ANT TIP HT - Antenna tip height, above the ground level. This is reference to the top of the antenna.
5. ECP - Executive Cellular Processor, or Mobile Telephone Switching Office (MTSO).

Below, are two geographic maps depicting the locations of the 18 cell sites. The sites are represented with different colors and shapes, to reference each market type.

Figure 3-1 Map of Cell Sites Tested

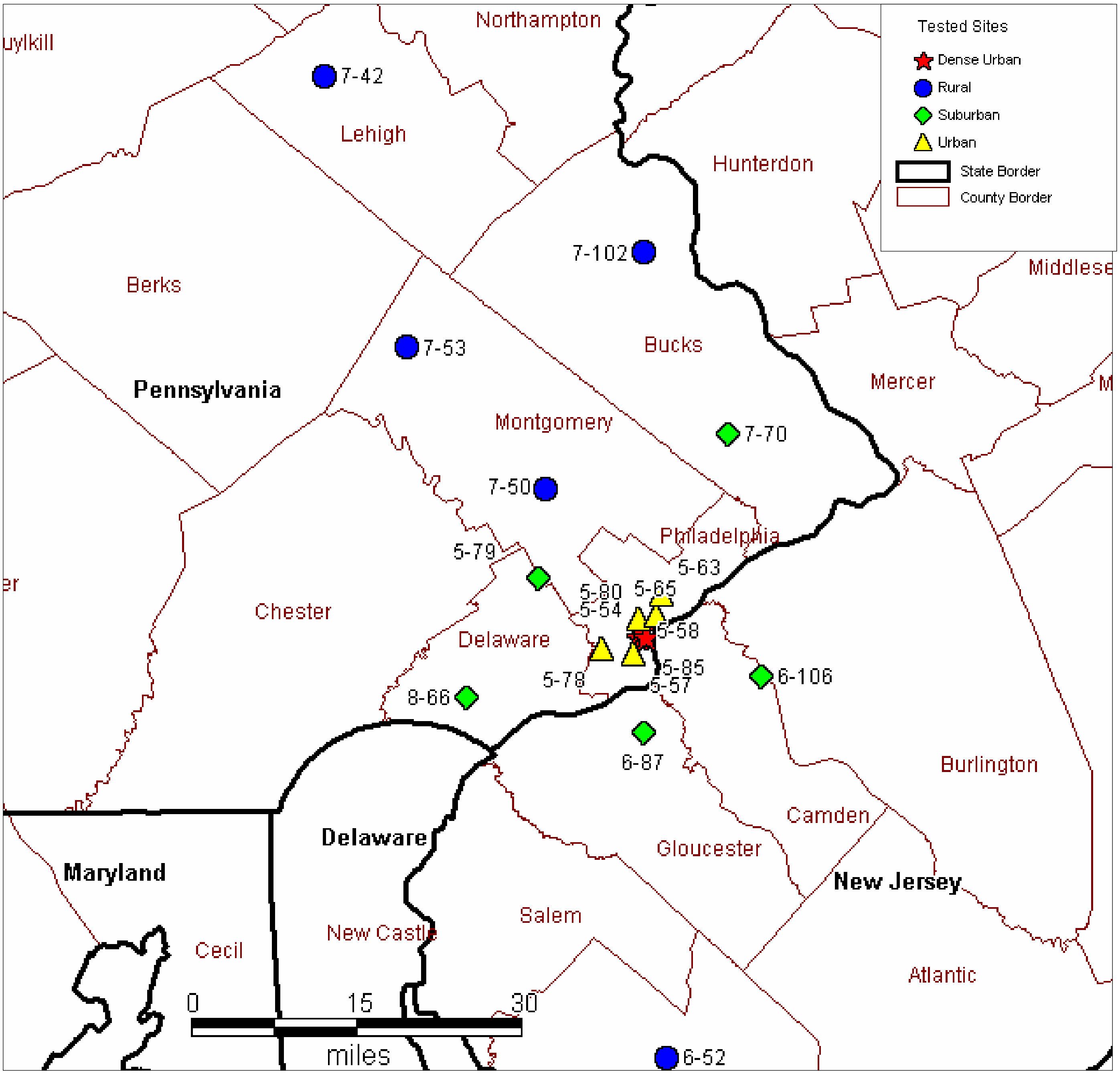
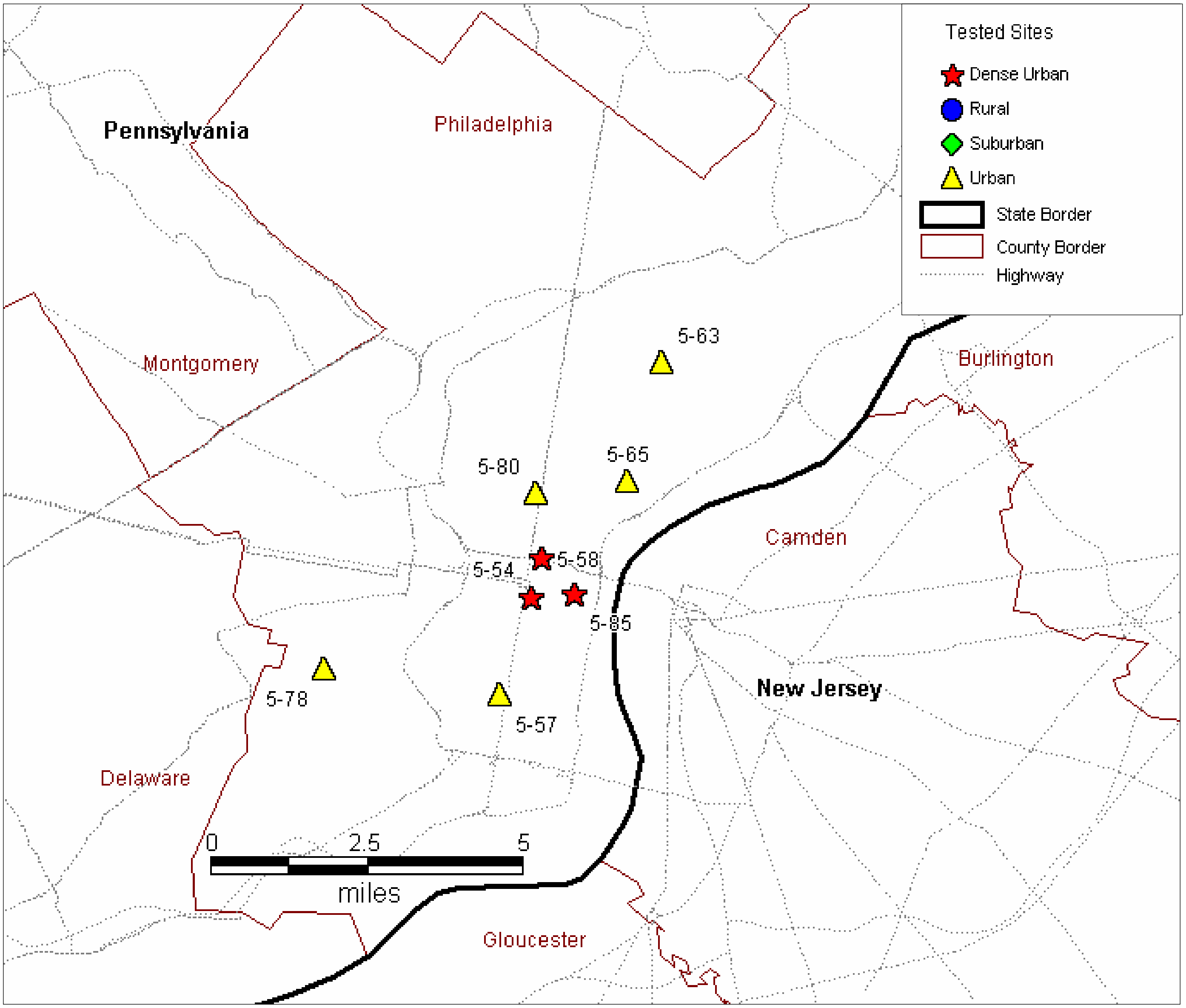


Figure 3-2 Zoom in Map of Cell Sites Tested



4. Test Procedures

4.1. Test Coordination

V-COMM worked with Verizon Wireless' regional performance and operations staff to execute this AMPS Noise Floor Study within the Philadelphia, PA and New Jersey market area. For each of the 18 sites tested, coordination of the required AMPS PLM and RF Traces settings, test mobile ID number (MIN), field engineering contact information, test meeting times, test plan activities and other cell site information was performed. The field tests were performed at each of the 18 cell sites on a typical business day, between the hours of 9:00 am to 3:00 pm. The field tests were performed within the months of December 2001, and January 2002.

4.2. Test Procedures

Upon arrival to the site, the HP 8921A Signal Generator was immediately powered up to allow for a minimum of a half-hour warm-up period, prior to testing. Then, using a test coaxial cable, the signal generator was connected to the –50 dB port of the directional coupler, for one receive diversity path. The switched diversity algorithm in the cell site's receiver selects this diversity since it is stronger than the background noise level on the other diversity. A cellular AMPS telephone call was made from the test mobile to the cell site landline telephone, and seized the desired AMPS voice radio and sector to be tested. The Nokia test phone displayed the channel number and SAT in the phone's test mode screen #1. The AMPS radio that was captured during this call, was located within the Radio Channel Frame (RCF) and the engineer verified that channel was within the desired sector to be tested. This transmit light on the radio was monitored during the test to verify the call was maintained. In addition, the audio was monitored on the landline phone, to verify the call was maintained on the cell site and for the duration of the test, once the signal generator captured the call.

The signal generator was used to capture this test call, by setting the generator to the same reverse channel frequency and supervisory audio tone (SAT) as the cellular AMPS telephone call. The battery was pulled off the cell phone (to prevent a termination signal being sent) and the signal generator was immediately turned on to maintain the call on the channel and cell site. Once the call was verified to remain on the radio channel for a 1 minute period, field tests #1 and #2 were performed. Both field tests use the signal generator modulating 2 tones:

1. The SAT to maintain the call (at either 5970, 6000, or 6030 Hz for SAT 0, 1, or 2; and a deviation of 2 kHz).

2. An audio tone to model typical voice channel characteristics (at 1 kHz frequency and 2.9 kHz deviation). The 1 kHz tone is also used to monitor the call, by listening on the landline phone.

Field Test #1

Using the calibrated signal generator connected to the –50 coupler port, with the proper offsets to reference the input of the cell site, a strong signal level was input into the cell site receive system. At the same time, the RF Call Trace was scheduled on the respective mobile phone number that started the test call, and measures the calibrated signal level over the duration of the test. The injected level was varied below this level, in 10 dB and then 1 dB increments, for fixed periods of time, to allow the RF Trace to provide consistent measurements for each signal level. This was continued all the way to the minimum signal level that would maintain the AMPS call on the channel with no audio muting of the receiver, as observed on the landline telephone.

The duration of this test was approximately 1 hour. The RF Trace data from this test was compared to the calibrated signal levels, to verify the accuracy of the AMPS radio receiver that was captured during the test. After this testing, the PLM was scheduled to measure the operating noise floor, over a 24-hour period, for the same radio channel receiver that was captured during this testing. The 50% PLM results are included in the "Test Results" section of this report and the individual site PLM graphs are included in the appendix of this report.

Field Test #2

Field test #2 takes place at the end of field test #1. The minimum signal level that can maintain an AMPS call with no audio muting is observed. This level is observed by decreasing the signal level 1 dB at a time, while listening to the audio tone on the landline telephone. At this minimum test call signal level, the operating noise floor during test can be estimated with the signal to noise ratio of approximately 2 dB.

At this level, the cell site receiver is able to maintain an AMPS call with 0% audio muting over a period of time of approximately 5 minutes. The call is maintained with the cell site radio receiver decoding SAT correctly and continuously, without interruption and without muting the receiver. The signal-to-operating-noise-floor level (S/N) is estimated to approximately 2 dB. If the signal is decreased below this level, the cell receiver will begin to lose the ability to decode the 6 kHz SAT (Standard Audio Tone - used to maintain calls), and will begin to mute the audio 1 kHz tone. Typically, 1 dB below this no muting "Minimum Test Call" signal level, the audio begins to mute approximately 5-10% of the time; 2 dB below this level the audio mutes approximately 50-60% of the time; and the call drops when the SAT Fade Timer is expired (typically 10 seconds). For this call testing, V-COMM estimates the cell site's operating noise floor is 2 dB below the no muting "Minimum Test Call" signal level.

To verify the approximate 2 dB S/N ratio provided above, two additional field tests were performed. The test results of these two tests support this S/N conclusion. Both tests involve similar test setups as used above. In the first test, using a strong signal the signal generator switches its output carrier on/off every 10 seconds to maintain a call on the site without dropping the call. This allows the cell site radio to measure the operating noise floor with the Lucent RF Call Trace function. The operating noise floor would be represented in the measured data, in alternating 10 second periods. The RF Trace has a measurement interval of 2 seconds and a resolution of 1 dB. In the second test, the signal generator performed a standard 12 dB SINAD audio test (Signal plus Noise and Distortion), with a 1 kHz tone and 8 kHz deviation. Lucent stated that the 12 dB SINAD point on their equipment is achieved with 4 dB S/N. The test results indicate the signal level to achieve 12 dB SINAD on the cell site was approximately 4 dB above noise floor, and approximately 2 dB above the “no muting” minimum call signal level test results. In conclusion, the results of both tests support the 2 dB S/N used in the test procedure above.

<u>Field Test #3</u>

Field test #3 takes place after field tests #1 and #2 are completed. The HP 8921A is set to its spectrum analyzer mode. The spectrum analyzer is connected to the cell site receive system, at the output port of the 1 to 9 splitter, at the top of the radio channel frame (RCF). The measured offset from this port to the input of the cell site, and the test cable loss, are used to reference the signal levels to the input of the cell site.

A snapshot of the average operating noise floor level is recorded during this test on the same radio receiver channel that was captured during field tests #1 and #2 above. The engineer verifies the radio channel is idle before taking these measurements. The results of these readings were equal to or lower than the estimated noise floor field tests, since the resolution bandwidth of the analyzer was narrower than the cell site receiver’s bandwidth.

5. Test Results

The AMPS Noise Floor Test Results are provided in Table 5.1. Included are the results from the field tests and 24-hour PLM measurements. For each of the 18 sites, the operating noise floor level is provided in two ways:

1. The distribution of operating noise floor measurements recorded by the 24-hour PLM. The individual PLM graphs for each site are provided in the appendix of this report. The PLM 50% threshold is the median operating noise floor for the cell site, over the 24-hour period.
2. The operating noise floor level observed during field testing, as estimated by the minimum test call signal level, that can maintain an AMPS call with no SAT muting.

In addition, Table 5.1 contains the minimum signal level that a “toll quality” AMPS call can be received by the cell site, with a carrier to interference (C/I) ratio of 17 dB (above the 50% PLM noise floor level). In the presence of considerable signal fading, an additional fade margin may be required. However, most cellular systems utilize diversity receive path systems, which mitigates the effects of signal fading.[1]

The results of the 50% PLM operating noise floor measurements, recorded over a 24-hour period by the cell site receiver for the 18 cell sites are –119 dBm to –127 dBm, with an average of –126 dBm. The 50% PLM operating noise floor levels, averaged per market type, for Dense Urban, Urban, Suburban and Rural sites are –123.4, –126.2, –127 and –127 dBm, respectively.

The estimated operating noise floor results, for day-time field tests within the 9:00 am - 3:00 pm time period, for the 18 cell sites are –118 dBm to –128 dBm, with an average of –125 dBm. The estimated field test operating noise floor levels, averaged per market type, for Dense Urban, Urban, Suburban and Rural sites are –121.7, –124.4, –126.4 and –126.6 dBm, respectively.

The minimum “toll quality” AMPS call signal level with a 17 dB C/I above the 50% PLM level, for the 18 cell sites are –102 dBm to –110 dBm, with an average of –109 dBm. The minimum “toll quality” AMPS call signal level, averaged per market type, for Dense Urban, Urban, Suburban and Rural sites are –106.4, –109.2, –110 and –110 dBm, respectively.

[1] Cellular base stations typically utilize diversity receive systems to mitigate the effects of signal fading. These systems utilize switched diversity receive or maximum ratio combining methods. As measured by Nokia in field tests, these systems provide between 2.7 to 5.7 dB of mean signal improvement depending on the radio environment and antenna used, over cellular systems not employing such equipment. Diversity receive systems providing link budget improvements up to 5.7 dB will mitigate the need for network fade margins in the same amount, or to approximately 5.7 dB. (This network fade margin assumes 8 dB standard deviation, 76% cell edge reliability, and approximalety 90% area coverage availability.)

The test results indicate very low cell site operating noise floor levels for the 50% PLM and Estimated Noise Floor During Test levels. The estimated noise floor during testing took place between 9:00 am and 3:00 pm, and the 24-hour PLM measurements includes the entire day-time and night-time periods for a typical weekday. The individual site PLM graphs are provided in the appendix of this report. These graphs show the distribution of operating noise floor levels over the 24-hour period, which includes system busy-hours (ie. 4:00 pm to 6:00 pm), where the cell site operating noise floor is higher than the 50% PLM values.

The AMPS Noise Floor Test Results are provided in Table 5.1 below. Included are the results from the field tests and 24-hour PLM measurements.

Table 5.1 AMPS Noise Floor Test Results

SITE	Market Type Classification	ECP	Cell	County, State	Minimum Test Call Signal (dBm) [1,2]	Est. Noise Floor During Test (dBm) [1,3]	Noise Floor Measurement PLM 50% (dBm) [1,4]	Min. Toll Quality Call Level, with 17 dB C/I (dBm) [1,5]
1	Dense Urban	5	54	Center City, Philadelphia, PA	-124	-126	-124.7	-108
2	Dense Urban	5	58	Center City, Philadelphia, PA	-119	-121	-127.0	-110
3	Dense Urban	5	85	Center City, Philadelphia, PA	-116	-118	-118.5	-102
4	Urban	5	80	Philadelphia, PA	-121	-123	-127.0	-110
5	Urban	5	63	Philadelphia, PA	-124	-126	-125.5	-108
6	Urban	5	65	Philadelphia, PA	-124	-126	-126.0	-109
7	Urban	5	78	Philadelphia, PA	-123	-125	-125.5	-108
8	Urban	5	57	Philadelphia, PA	-120	-122	-126.9	-110
9	Suburban	2	87	Gloucester, NJ	-126	-128	-127.0	-110
10	Suburban	2	106	Camden, NJ	-124	-126	-127.0	-110
11	Suburban	7	70	Bucks, PA	-124	-126	-127.0	-110
12	Suburban	8	66	Delaware, PA	-126	-128	-127.0	-110
13	Suburban	5	79	Delaware, PA	-122	-124	-127.0	-110
14	Rural	6	52	Cumberland, NJ	-124	-126	-127.0	-110
15	Rural	7	50	Montgomery, PA	-125	-127	-127.0	-110
16	Rural	7	42	Lehigh, PA	-125	-127	-127.0	-110
17	Rural	7	53	Montgomery, PA	-125	-127	-127.0	-110
18	Rural	7	102	Bucks, PA	-124	-126	-127.0	-110
				Average	-123.1	-125.1	-126.2	-109.2

Table 5.2 AMPS Noise Floor Test Results, Averaged by Market Type

Market Type Classification	Average per Classification			
	Minimum Test Call Signal (dBm) [1,2]	Est. Noise Floor During Test (dBm) [1,3]	Noise Floor Measurement, PLM 50% (dBm) [1,4]	Min. Toll Quality Call Level, with 17 dB C/I (dBm) [1,5]
Dense Urban	-119.7	-121.7	-123.4	-106.4
Urban	-122.4	-124.4	-126.2	-109.2
Suburban	-124.4	-126.4	-127.0	-110.0
Rural	-124.6	-126.6	-127.0	-110.0

Notes for Tables 5.1 and 5.2:

1. All signal level units are in dBm, referenced to the input to the cell site. Lucent references this as the J1 port. This reference is the antenna side connector of the very first element in the cell site receive system; which is the same reference as the equipment side of the antenna jumper cable, which connects to the transmission line.

2. Minimum Test Call Signal (dBm) - This is the minimum signal level that the cell site receiver is able to maintain an AMPS call, with 0% audio muting over a period of time of approximately 5 minutes, during testing. The test call occurred between the weekday hours of 9:00 am to 3:00 pm. The test call used a modulated 1 kHz audio tone, with 2.9 kHz deviation, to represent average voice channel characteristics. At the minimum test call level, the call is maintained on the cell site and SAT is decoded properly and continuously, without interruption or muting. At this level, the signal-to-operating-noise-floor level (S/N) is estimated to 2 dB. If the signal is decreased below this level, the cell receiver will begin to lose the ability to decode the 6 kHz SAT (Standard Audio Tone - used to maintain calls), and will begin to mute the audio tone.

3. Est. Noise Floor During Test (dBm) - This is the estimated cell site operating noise floor, that is computed from the "Minimum Test Call Signal" level. This is 2 dB below the "Minimum Test Call Signal" level. See previous note for further explanation.

4. Noise Floor Measurement, PLM 50% (dBm) - This is the cell site's 50% median operating noise floor level, as measured over a 24-hour weekday period. This is provided by the Lucent Power Level Measurement (PLM) Mode 2 function, which measures the operating noise floor level on an idle AMPS channel and records signal levels into 3.125 dB bins. With

this resolution, the measured data is +/- 1.562 dB. The signal level of each bin is referenced to the center of the bin. The PLM 50% threshold is provided as the median operating noise floor, from the cumulative probability series. Linear interpolation is used for values that are contained between 2 data points. If the 50% cumulative probability occurs within the lowest bin, the –128.6 dBm bin, linear interpolation cannot be performed and the upper edge of the bin is used, which is –127.0 dBm.

5. Min. Toll Quality Call Level, with 17 dB C/I (dBm) - This is the minimum signal level that a "Toll Quality" AMPS call can be made on the cell site, with a carrier-to-interference ratio of 17 dB. This level is computed by adding 17 dB to the "Noise Floor Measurement, PLM 50%" values.

6. Analysis of Test Results and Noise Floor Issues

6.1. Cell Site Operating Noise Floor in Today's Cellular Networks

The test results indicate that very low operating noise floor levels exist in today's cellular AMPS networks. The noise floor is lower than it has been in the past. Over the past years, cellular networks have experienced a quieting affect to their operating noise floors for a variety of reasons. Some of these reasons are provided below.

Cellular Portable Phones – Cellular portable phones are the most prevalent phones in the market, representing close to 100% of the cellular phones that exist today. In the past, cellular car phones were more common. The AMPS cellular car phone transmits maximum power at 3 watts, into a 3 dB gain antenna, and the AMPS portable phone only transmits maximum power at 0.6 watts, into a 0 dB gain antenna. This is approximately an 10 dB reduction in signal strength of the cellular phones, which translates to lower signal and operating noise floor levels seen by the cellular base stations. In addition, portable phones used inside cars experience additional attenuation, due to the placement of the phone's antenna within the car (especially when used with a headset, with the phone on the seat or in a cradle). This attenuates the signal path by an additional 5 to 10 dB.

In-building Cell Phone Usage – The percentage of people using cell phones inside buildings has increased over the past years. This trend has the affect of dramatically lowering the signal and operating noise floor seen by cellular base stations. The decrease in signal and noise levels from in-building cell phone users are approximately 10 to 30 dB, due to the signal attenuation of the building structure.

Cell Sites Using Sector Antennas – The most common cellular base station antenna today is the 3-sectored panel antenna. The panel antenna improves the performance of cellular systems by achieving more gain in the intended 120 degree sector coverage area, and more protection from interference in the other 240 degrees. This allows the cell site to achieve lower operating noise floor conditions, from nearby co-channel and adjacent channel interference. The sector antenna's interference noise floor reduction will be in the range of 5 to 30 dB, depending on the antenna's horizontal beam-width pattern. In addition, the interference noise floor can be lower in cases when the antenna is mounted on a water tank or building wall, which further attenuates the interference from these directions. In the past, omni-directional antennas were more common than they are today. Omni-directional antennas have gain in all directions (360 degrees) and consequently experience higher noise floor levels.

Mature Cellular Networks – The use of cellular service has increased dramatically over the past years. Cellular networks have matured and evolved to meet this growing demand. Mature cellular systems exhibit the following trends in network design.

1. Smaller cell sites with lower antenna elevations (closer to the height of the clutter of trees and buildings). This lowers the operating noise floor of the cell site, and increases system capacity. Smaller cell sites allow mobile phones to operate at lower power levels, which in turn lowers the interference levels received by the co-channel and adjacent channel cell sites.
2. Downtilting antennas are commonly used in mature cellular systems to lower the cell site's interference noise floor.
3. Narrow horizontal beam-width antennas are used to reduce the cell site's interference noise floor, by limiting the interference that can be seen from the edges of the sector antenna. Antennas with horizontal beam-width of 60 to 80 degrees are becoming more common in mature systems.
4. The cell site Voice Mobile Attenuation Code (VMAC) parameter is utilized by some cellular systems, to lower the maximum allowable AMPS mobile phone power, which in turn reduces the surrounding cellular system's interference noise floor.

The above trends in cellular system usage and network design have contributed to lowering the cell site's operating noise floor. The results of this AMPS Noise Floor Study exhibit this trend.

6.2. Other Technology and Cell Site Equipment

Cell sites included in this study use standard and typical cell site equipment. Many cellular operators use other technology and cell site equipment, which have different noise floor characteristics. Examples of other technology and cell site equipment that offer lower operating noise floors than the standard AMPS cell site equipment, are provided below.

<u>Tower-top Low-Noise Amplifiers (TLNA)</u> - offer cellular systems lower system noise figures (by approximately 2 dB), which allows the cell site to exhibit a lower operating noise floor.

<u>Superconductor receive filter and preamplifier equipment</u> - offer cellular systems lower system noise figures (by approximately 1 to 2 dB), which allows the cell site to exhibit a lower operating noise floor.

<u>Smart antenna technology utilizing micro-sector antennas</u> - exhibit lower operating noise floor levels, due to the interference protection provided by the antenna's horizontal beam-width characteristics. Typical horizontal beam-width specification for this application is 30 degrees.

<u>Smart antenna technology utilizing adaptive array antenna systems</u> - exhibit lower interference noise floor levels, due to interference reductions provided by interference nulling and canceling algorithms.

Narrow-band AMPS (NAMPS) cell site equipment - this cell site equipment was offered by Motorola years ago and still exists in some cellular networks today. The cell site radio equipment for NAMPS uses a 10 kHz bandwidth, as compared to the standard AMPS 30 kHz bandwidth. With 1/3 the bandwidth, the NAMPS receiver has a thermal noise floor that is 4.7 dB below the AMPS receiver, which allows it to exhibit lower noise floor conditions.

Six-sectored cell sites - may exhibit lower operating noise floor levels, due to interference protection provided by the antenna's horizontal beam width characteristics. Typical horizontal beam width specifications for this application is 50 to 60 degrees. This application is not common, but may exist in some cellular systems today.
(If the six-sector network design is used in conjunction with a frequency reuse of N=4, then system interference levels will not decrease, due to increased co-channel usage.)

6.3. Cell Site Equipment System Noise Floor

The cell site's *system* noise floor is the lowest noise level that can be achieved by the cell site receive system. It is represented below in two separate analyses. The first method uses the thermal noise floor plus the equipment's system noise figure, and the second uses the Signal plus Noise and Distortion (SINAD) measurement to compute the equipment's system noise floor. The noise floor level varies across some radio receivers and cell sites. Included in these analyses are approximate values and assumptions for the characteristics that contribute to the system noise floor.

Method #1
The first method uses the thermal noise floor plus the equipment's system noise figure to calculate the cell site *system* noise floor.

Cell Site System Noise Floor = Thermal Noise Floor + System Noise Figure

System Noise Figure – The cell site receive system begins at the input to the cell site (J1 port) and ends at the radio. The system noise figure is equal to the noise contributions all the devices in this path, however it is primarily controlled by the front end of the receiver. The front end consists of receive system filters, couplers and the preamplifier. As provided by Lucent, a typical system noise figure for the Series 2 cell site is 3.7 dB. Lucent's manufacturing guaranteed noise figure is 5 dB, which is a conservative, maximum value. The minimum value can be lower than the typical; however Lucent did have this information available. For this analysis, the typical value for the Series 2 cell site *system* noise figure is used, which is 3.7 dB.

Thermal Noise Floor – The thermal noise floor is calculated with the formula = kTB, where k is Boltzmann's constant k = 1.37 x 10^{-23} joules/Kelvin, T is the temperature in Kelvin, and B is the bandwidth of the receiver. Using 290 degrees K room temperature, the thermal noise floor is –129.2 dBm, –130.2 dBm, and -130.6 dBm for receiver bandwidths of 30 kHz, 24 kHz and 22 kHz, respectively. Depending on the actual bandwidth characteristics of the AMPS cell site receiver, its thermal noise floor will vary slightly. The AMPS cellular standard uses 30 kHz bandwidth channel spacing to define the AMPS channel's nominal bandwidth,[2] however the signal level at +/- 15 kHz from the center of the carrier is sufficiently lower to meet the receiver adjacent channel rejection specifications and improve receiver sensitivity. In addition, the AMPS cell site receivers must have bandwidth characteristics wide enough to demodulate voice signals (typically 300 to 3 kHz), SAT tones (6 kHz) and Signaling tones (10 kHz) such as power control and handoff messages.

Lucent did not specify the actual bandwidth characteristics of its cell site receivers, however they performed receiver band pass measurements on the AMPS Series 2 cell site receiver.[3] V-COMM analyzed these measurements for the actual receiver bandwidth characteristics, and concluded the actual bandwidth is approximately 24 kHz. For this analysis, the AMPS receiver is assumed to operate with the bandwidth characteristics of 24 kHz. With this receiver bandwidth characteristic, the Lucent Series 2 cell site's thermal noise floor is –130.2 dBm.

Cell Site Equipment's *System* Noise Floor – With a thermal noise floor of –130.2 dBm and typical noise figure of 3.7 dB, the cell site's *system* noise floor is –126.5 dBm.

<u>Method #2</u>
The second method uses the Signal plus Noise and Distortion (SINAD) audio measurement to compute the equipment's system noise floor. The cell site's *system* noise floor is computed with the signal to noise (S/N) ratio that is required to achieve 12 dB SINAD (referenced in audio) on the Lucent Series 2 AMPS cell site receiver. As provided by Lucent, this S/N ratio is 4 dB (referenced in RF). V-COMM performed measurements at the Series 2 cell site, and measured the 12 dB SINAD level to –123 dBm.[4] With this signal level and S/N ratio above, the cell site *system* noise floor is equal to –127 dBm.

As provided in the two analyses above, the cell site *system* noise floor is estimated to approximately –127 dBm. Comparing the –127 dBm *system* noise floor level to the lowest readings in the test results, we observe that the lowest readings are at or slightly below this level. However, the cell site receiver should not be able to distinguish signals

---

[2] The transmitted emissions of analog cellular signals are attenuated by approximately 24 to 28 dB, at its nominal channel bandwidth (i.e. +/- 15 KHz from its center frequency).

[3] Lucent conducted measurements on a series II cell site AMPS radio in its laboratory. For these tests, an unmodulated signal reference was injected into the AMPS radio at various offset frequencies from the radio channel's center frequency, to determine the receiver's actual pass band characteristics.

[4] The SINAD performance of cell site equipment may vary slightly from site to site. In another test, at a different Lucent Series 2 AMPS cell site, V-COMM measured the 12 dB SINAD reference point to –122 dBm. Utilization of external LNA configurations (ie. Tower-top) or superconductor filters will improve and lower these system noise floor and sensitivity figures further, by approximately 2 dB (i.e. to –124 dBm). These levels are referenced to the input to the cell site. These low receive sensitivity levels allow cellular operators (and AirCell, since they reuse the same AMPS cell site equipment) to serve calls to very low signal levels. At the Marlboro AirCell site, AirCell sets the lower end of its DPC power box equal to –120.5 dBm, which results in a C/N of approximately 6 to 6.5 dB at the lower end of the power box, with an equipment noise floor of –126.5 to –127 dBm.

or noise below its system noise floor level. Some possible reasons for this occurrence are provided below.

1. Some radio receivers may be more sensitive than others and some receive paths may have lower noise figures than others, which improves the cell site system noise floor. This allows the radio to distinguish signals and noise levels that are lower than the assumptions indicate in the analyses above.
2. The resolution of PLM measurement uses 3.125 dB bin sizes, and records data within +/- 1.562 dB from the center of the bin. For example, the lowest bin is centered at –128.6 dBm, and it records data from –130.2 to –127.0 dBm. The –127 dBm value is within its +/- 1.5 dB bin resolution.
3. The accuracy of the PLM and RF Trace measurements are approximately within +/- 1 dB, and the differences above are within its measurement tolerance.
4. The accuracy of the signal generator is +/- 1 dB, and the differences above are within its measurement tolerance.

In another observation, it is observed that that the suburban and rural cell sites tested exhibit very low cell site operating noise floor levels that approach the cell site equipment's *system* noise floor level, for a good percentage of the day. The operating noise floor increases above this level at other times during the day, but this occurs for shorter periods of time. The distribution of operating noise floor levels over a 24-hour period are provided in the PLM graphs in the report's appendix section.

7. Conclusion

The results of the AMPS Noise Floor Study show very low noise floor levels present in today's cellular networks. These levels are lower than systems have been in the past, due to trends in cellular system usage and cellular system design (see section 6.1).

The results of the 24-hour noise floor measurements, for the 18 cell sites, range from –119 dBm to –127 dBm, with an average of –126 dBm. With 17 dB C/I, "toll quality" AMPS calls can maintain service to very low levels at these cell sites, from –102 to –110 dBm, with an average of –109 dBm. The results of the day-time noise floor field tests range from –118 dBm to –128 dBm, with an average of –125 dBm.

Based on the results of this study, the operating noise floor level for AMPS cellular systems is represented by –123 dBm for Dense Urban markets, –126 dBm for Urban markets, and –127 dBm for Suburban and Rural markets. These levels represent the operating noise floor for the 18 cell sites, averaged by market type and measured over a 24-hour period for a typical business day. AMPS cellular systems using other cell site equipment, such as tower-top LNA, superconductor or smart antenna technology described in section 6.2, offer cell site operating noise floor levels that are lower than the levels provided in this report.

In addition, the test results indicate the following conclusions:

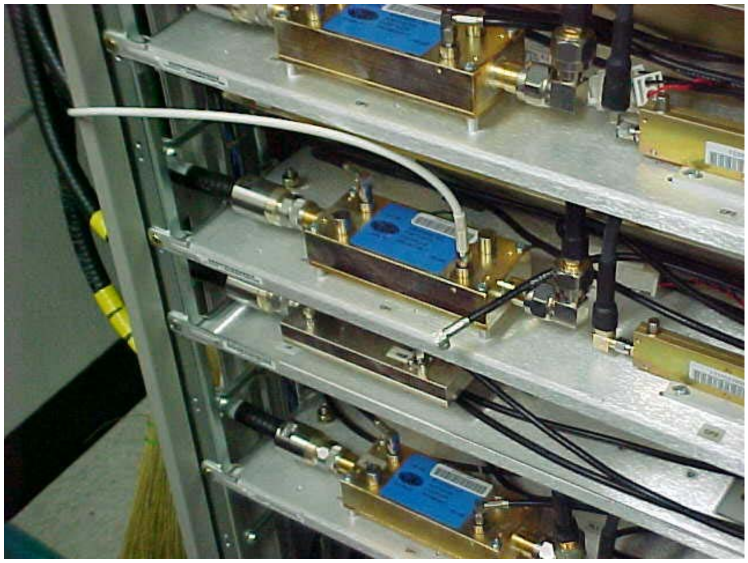
1. The operating noise floor levels for the Rural and Suburban sites indicate similar and very quiet noise conditions. With the current market trends (in-building cell phone users and the maturity of cellular systems), Suburban site noise floors conditions have approached the Rural site conditions.
2. The operating noise floor levels for the Rural and Suburban sites approach the cell site's *system* noise floor levels between 55% to 98% of the 24-hour business day period.
3. The operating noise floor levels for the Urban and Dense Urban sites are higher than the Suburban and Rural sites, by 1 dB, and 4 dB, respectively, based on the 50% PLM measurements.
4. The 50% PLM noise floor level shows a correlation to the estimated noise floor level during testing. When comparing the average of these the two levels, it shows the estimated day-time field test noise floor 1 dB higher. This is expected due to the elevated noise floors that occur during busier day-time periods, and the PLM measurements are averaged over a longer 24-hour period.

8. Appendix

8.1 Pictures of Test Setup

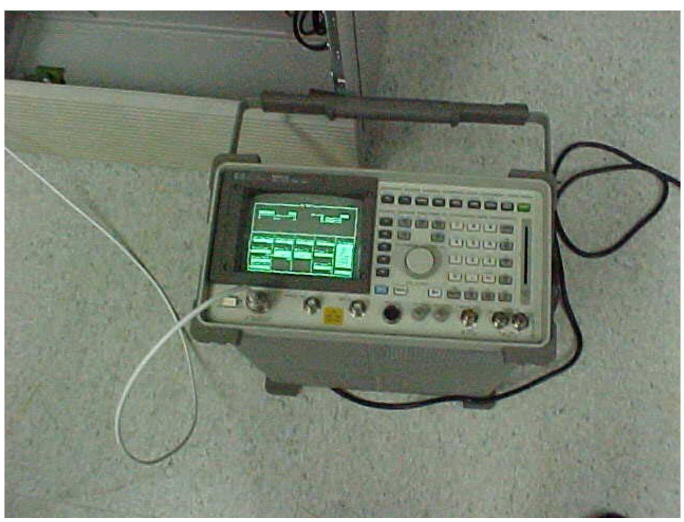
Picture 1 -- Test Setup

This photo illustrates the connection of the HP 8921A Signal Generator to the -50 dBm receive coupler port, which was used for calibrated signal level injections during field tests #1 and #2. This coupler is the 1st element in the cell site's receive path, within the Lucent Series 2 cell site antenna interface frame (AIF).



Picture 2 – Receive Coupler Port

This is a close-up photo of Picture 1, showing the test cable connected to the–50 dB receive coupler.



Picture 3 -- Cell Site Analyzer

This is a photo of the HP 8921A Signal Generator / Spectrum Analyzer used to perform the AMPS Noise Floor field tests #1, #2 and #3.

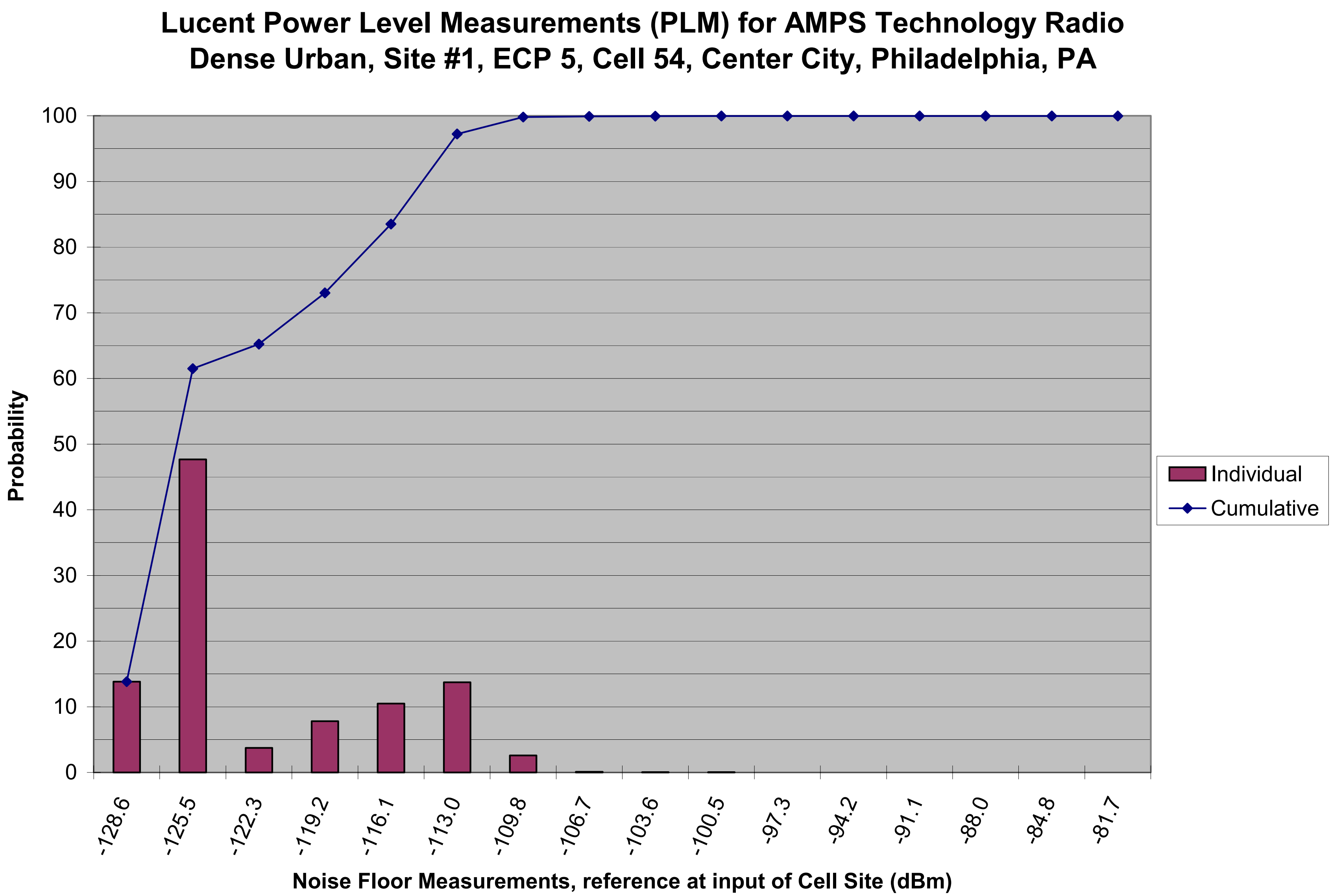
8.2 PLM Graphs of Cell Sites

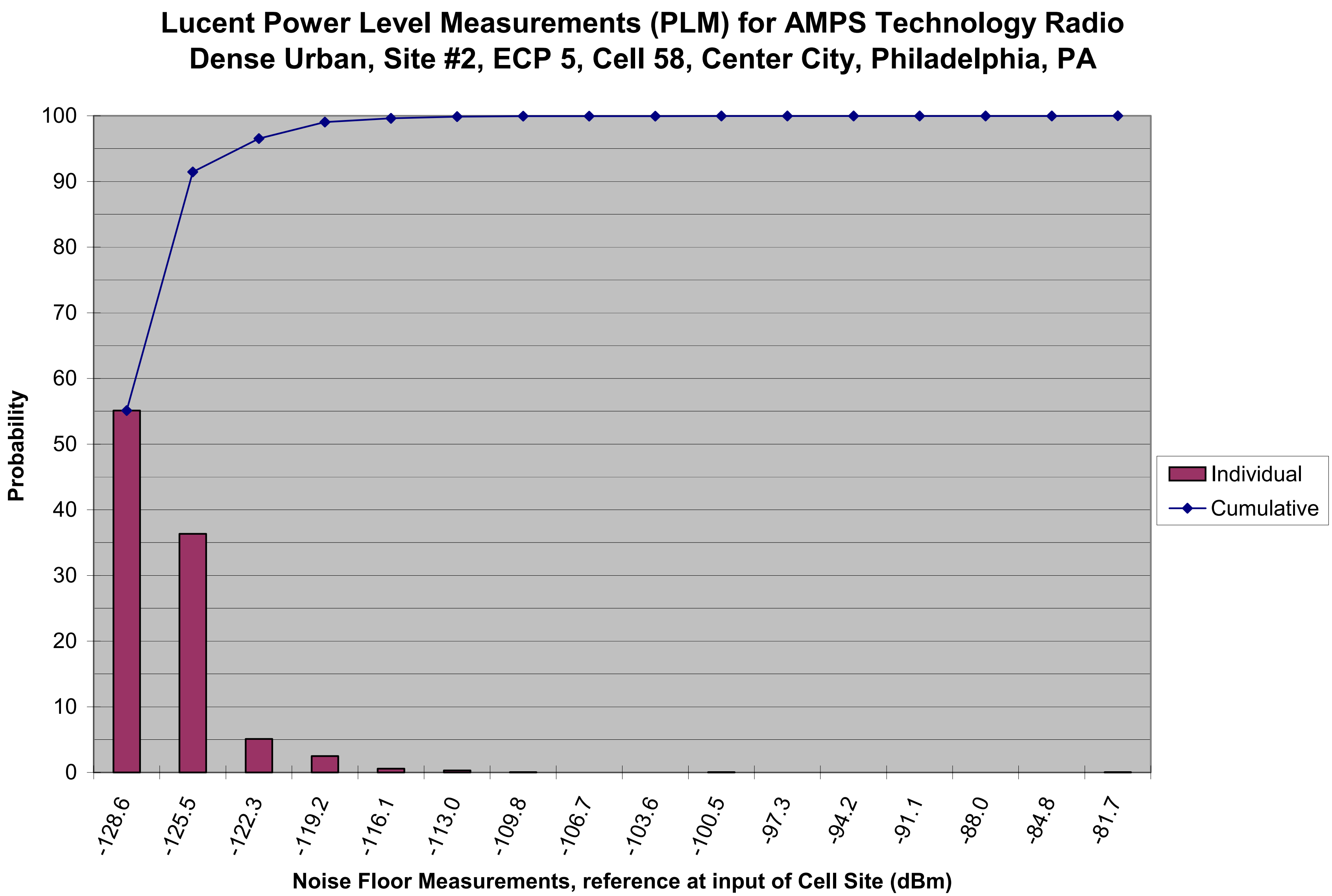
The following 18 pages contain the PLM graphs of the 18 cell sites included in the AMPS Noise Floor study. The PLM graph represents the cell site's operating noise floor level distributions over a 24-hour period, as recorded by the Lucent PLM function. The PLM function records the noise floor measurements on an idle AMPS channel with the cell site receiver. The Lucent PLM measurements are collected into "bins" that are 3.125 dB in width. The reference value of each bin is the center value of the bin, and is represented by the x-axis value on the graphs. With this bin size and reference, each bin includes measured data that is 1.562 dB above and below the reference value. For example, the measured data contained within the 1st bin, at the –128.6 dBm level, includes data that is greater than –130.2 dBm and less than –127.0 dBm.

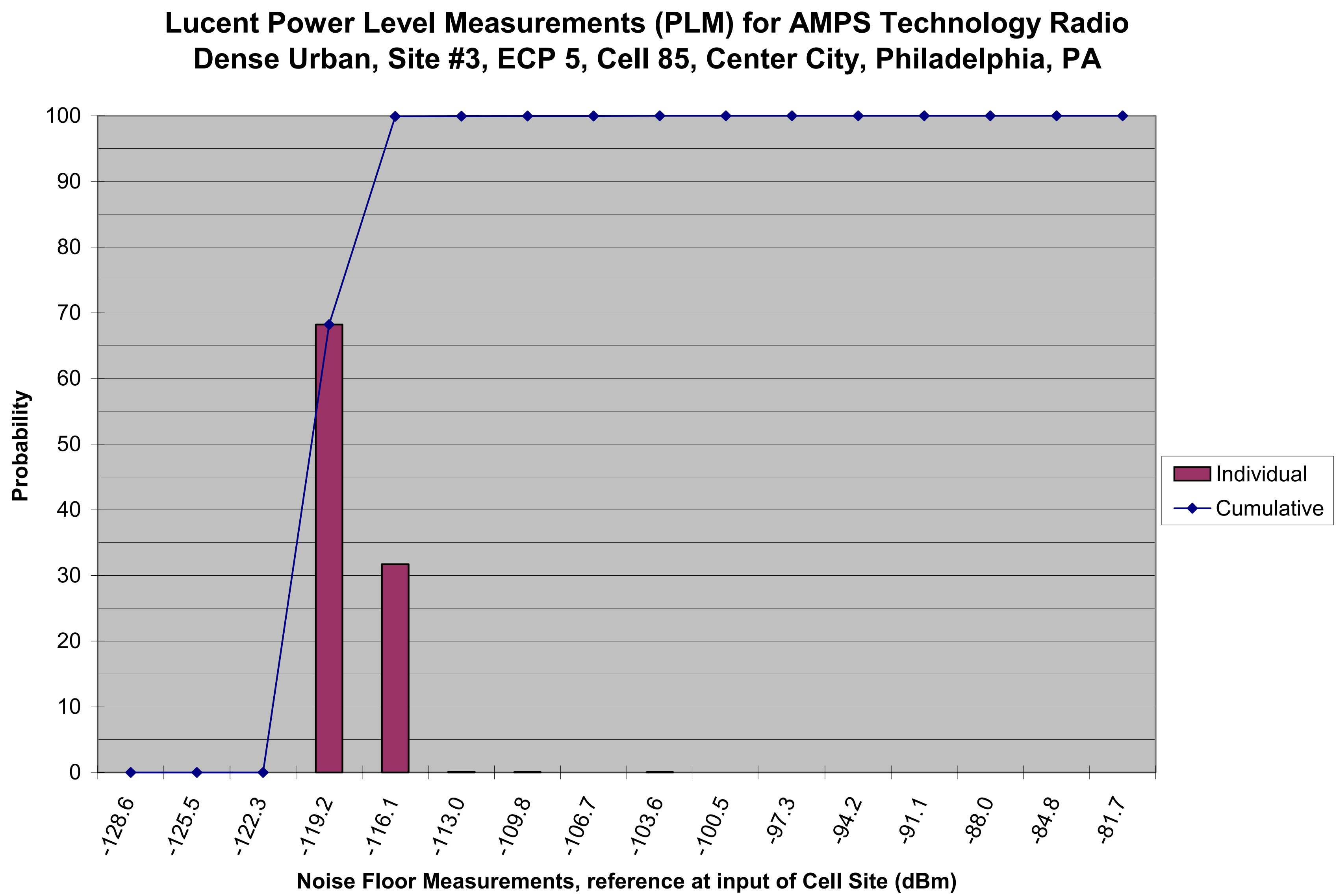
The PLM graphs contain the Individual Probability and Cumulative Probability distributions. The Individual Probability is the probability of occurrence of an individual bin or data point. The reference value of this data is represented by the average value of the bin, which is the center of the bin. The Cumulative Probability is the probability of occurrence of an individual bin, plus the accumulation of all prior bins starting from the minimum value on the x-axis. The reference value of this data is represented by the upper value of the bin, since all the data within the bin must be included. The upper value of the bin is 1.562 dB above the center value of the bin.

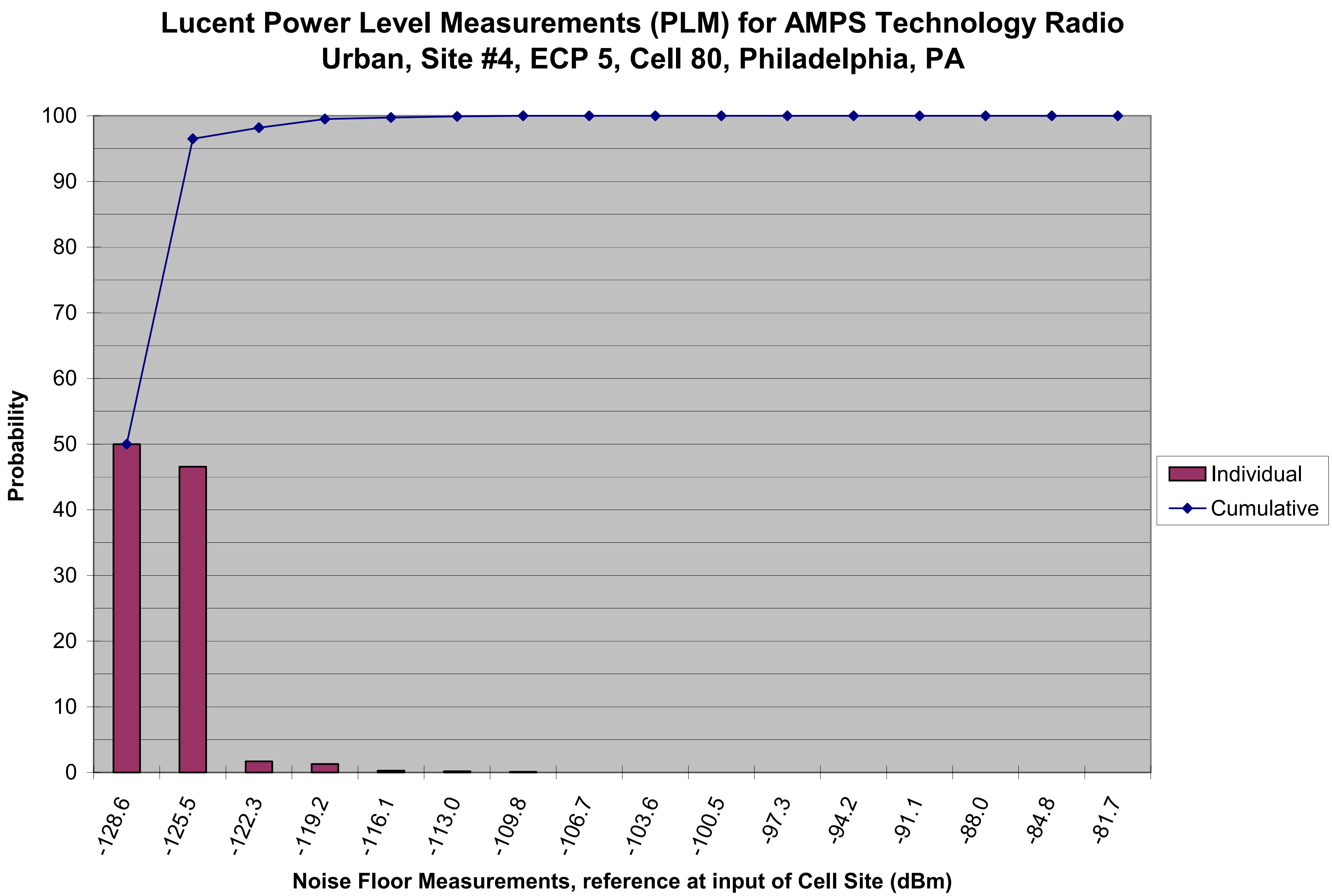
Two examples for the 1st PLM graph are as follows. Site #1 has an operating noise floor level that occurs at the –125.5 dBm level 48% of the time. The –125.5 dBm level is the average for the bin; it includes signals measured from –127.0 dBm to –123.9 dBm. In addition, 61% of the time the operating noise floor level is below –123.9 dBm. This is the cumulative probability, which is referenced to the upper value of the bin. This upper value is equal to –123.9 dBm, which is derived from –125.5 dBm + 1.562 dB.

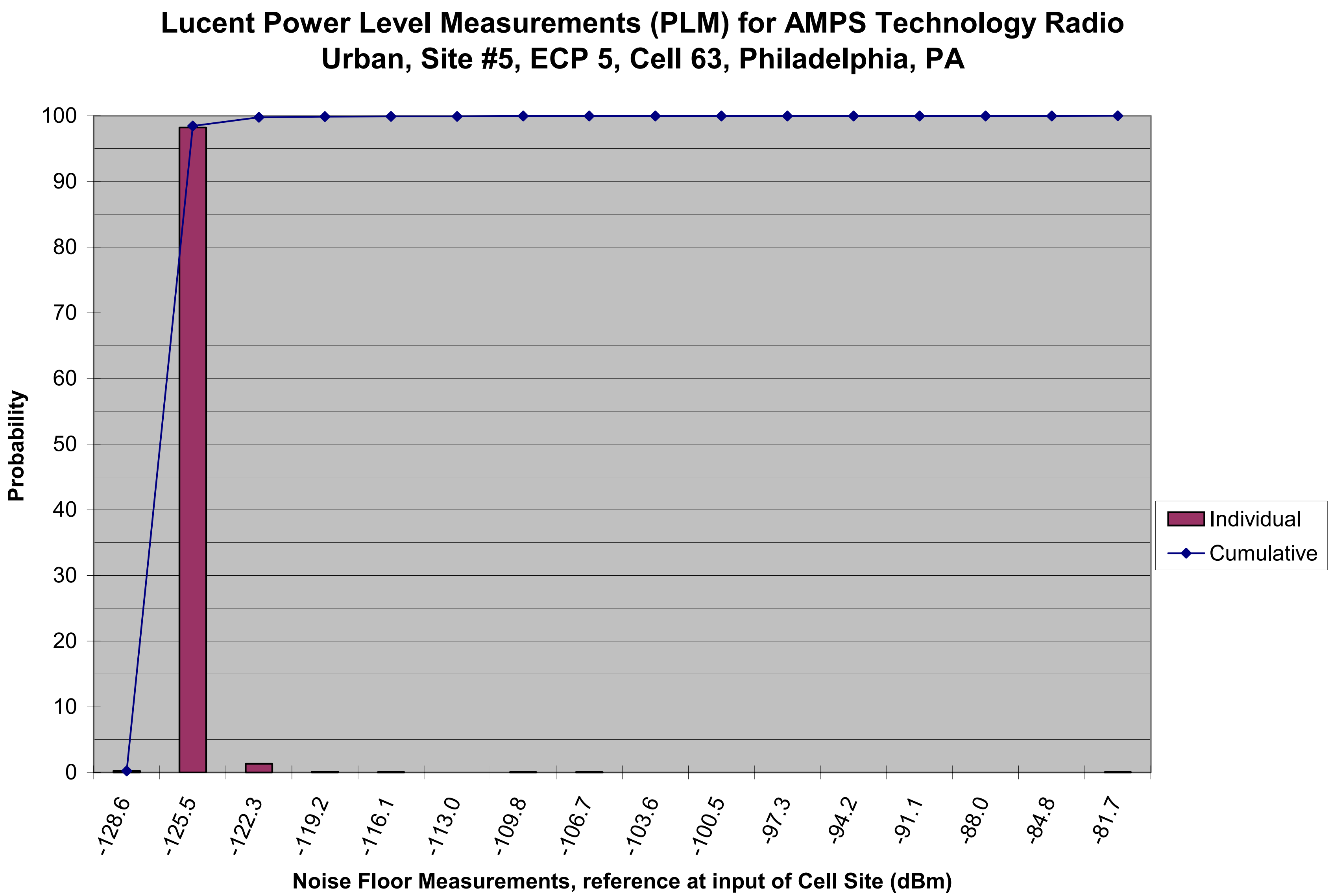
The AMPS Noise Floor Test Results in Table 5.1, includes the PLM 50% threshold as the median operating noise floor for the cell site. The PLM 50% noise floor is calculated from the cumulative probability series. Linear interpolation is used for values that are contained between 2 data points. If the 50% cumulative probability occurs within the lowest bin, the –128.6 dBm bin, linear interpolation cannot be performed and the upper edge of the bin is used, which is –127.0 dBm.

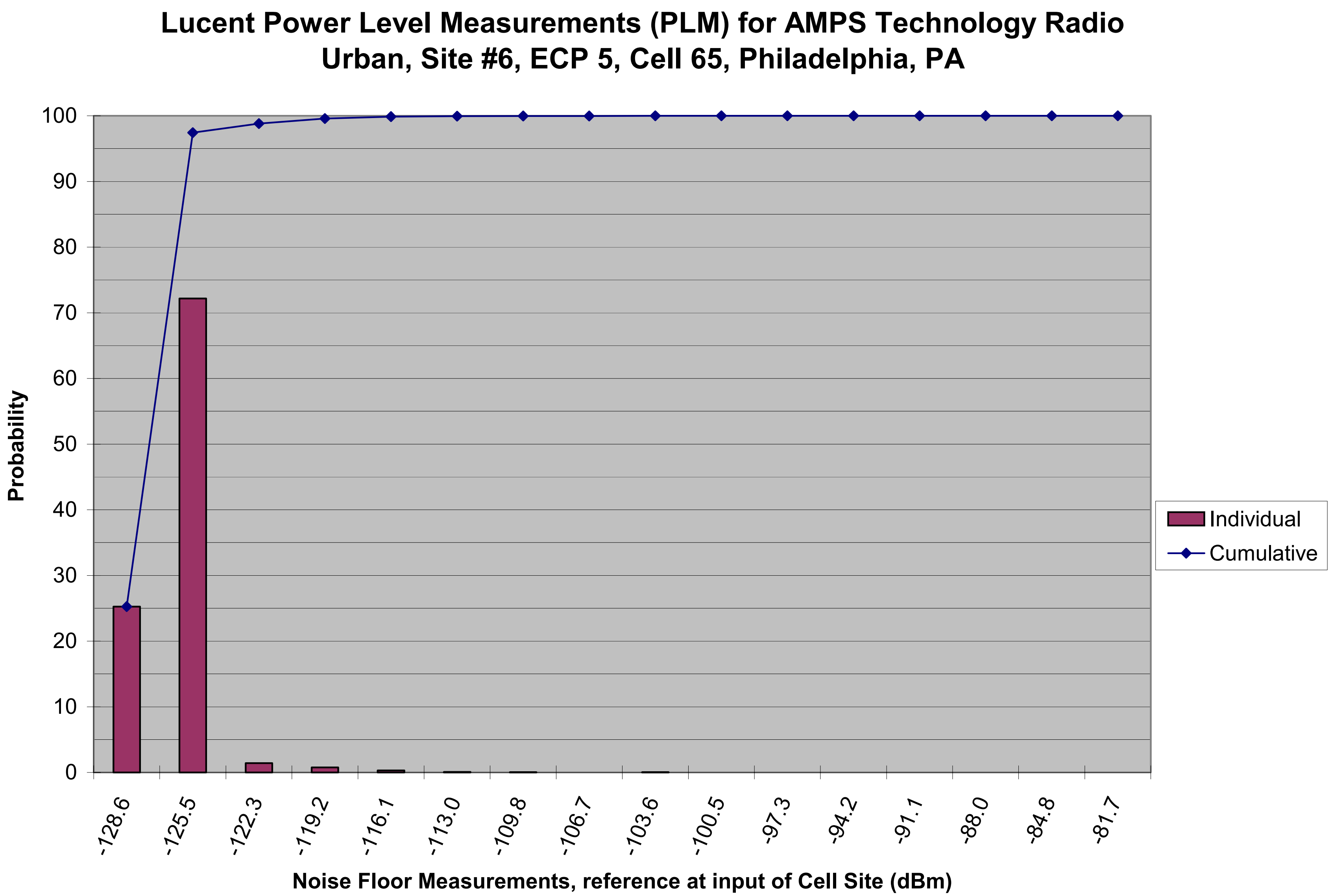

Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Dense Urban, Site #1, ECP 5, Cell 54, Center City, Philadelphia, PA
Probability
100
90
80
70
60
50
40
30
20
10
0
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative

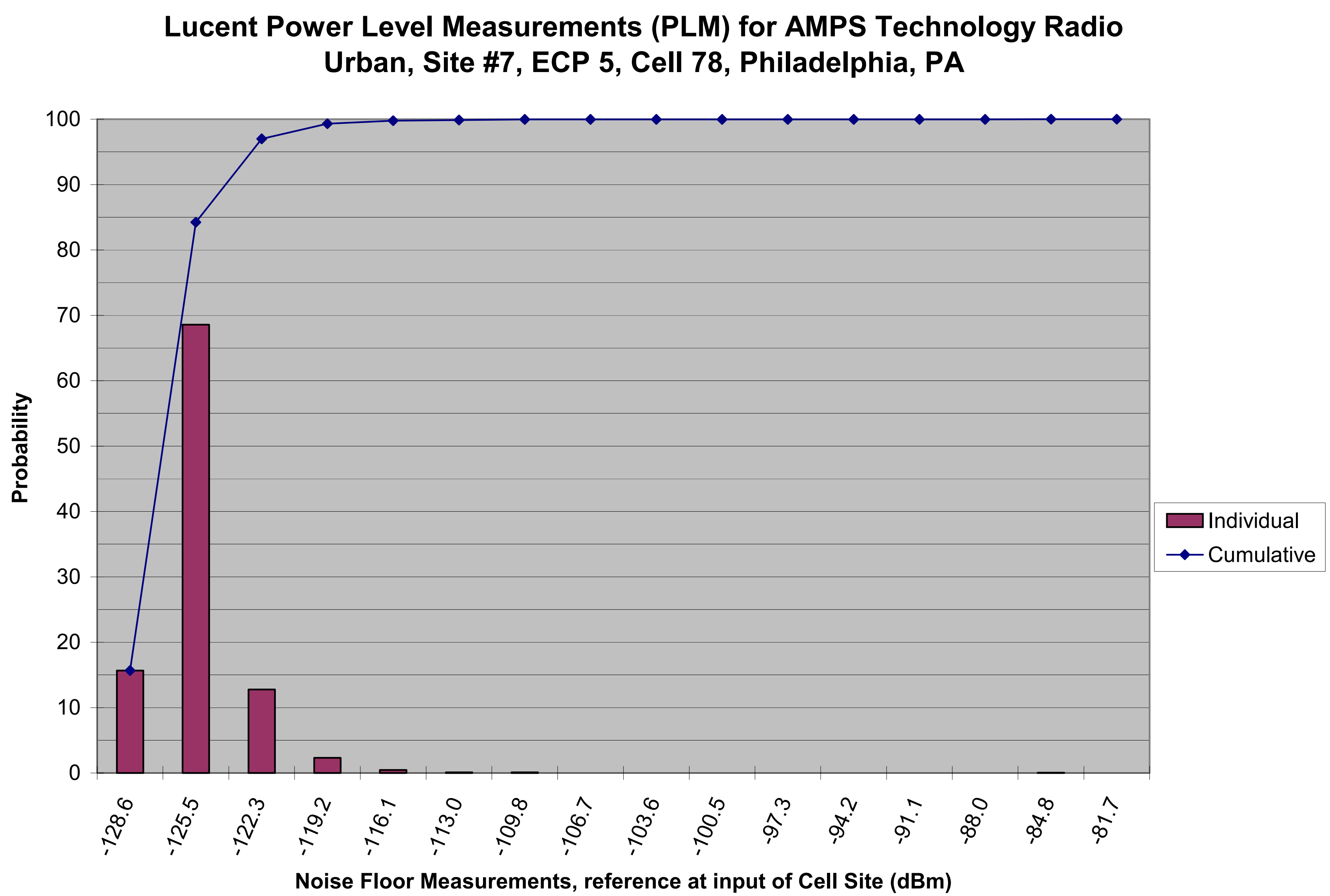

Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Dense Urban, Site #2, ECP 5, Cell 58, Center City, Philadelphia, PA
100
90
80
70
60
50
40
30
20
10
0
Probability
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative

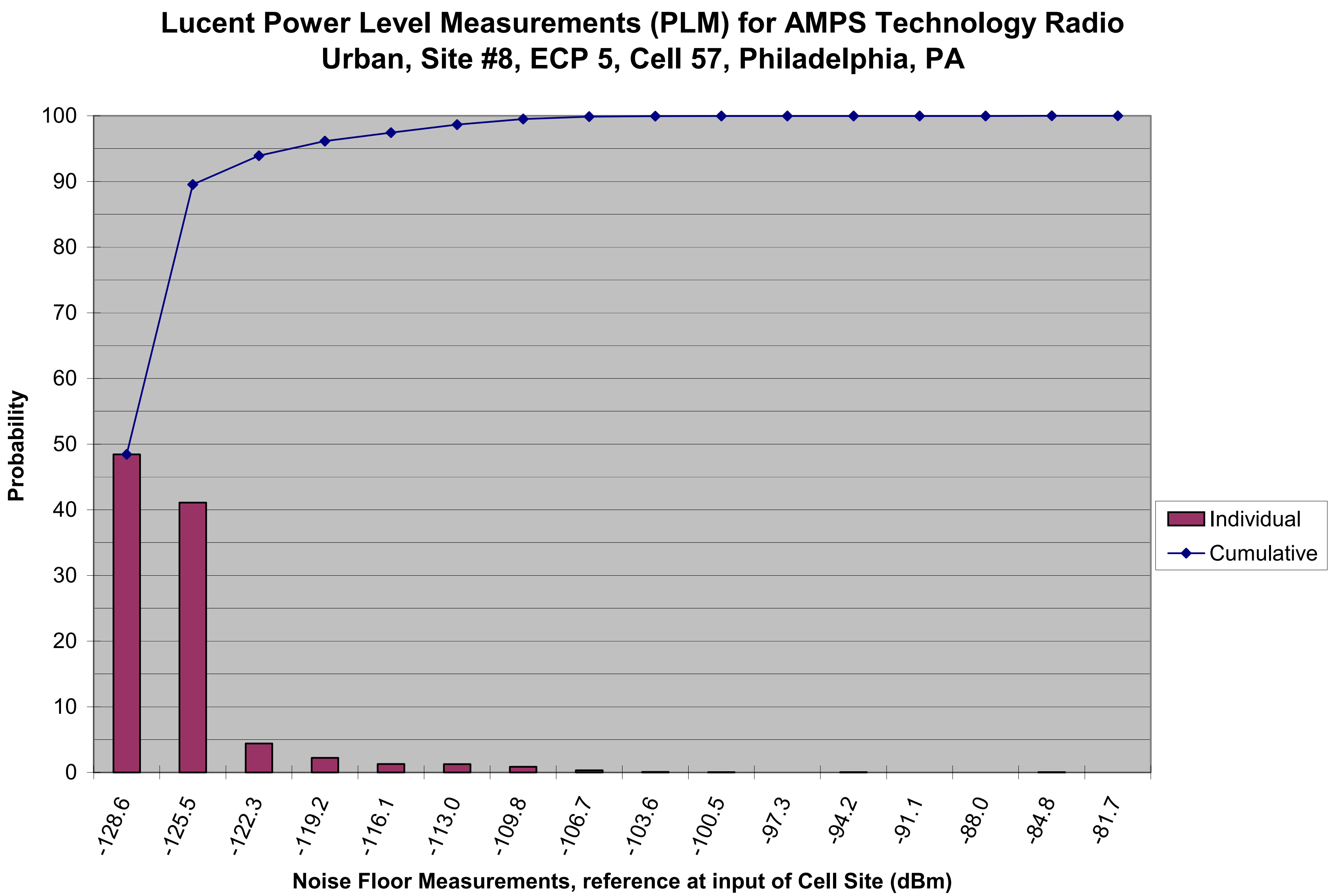

Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Dense Urban, Site #3, ECP 5, Cell 85, Center City, Philadelphia, PA
100
90
80
70
60
50
40
30
20
10
0
Probability
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative

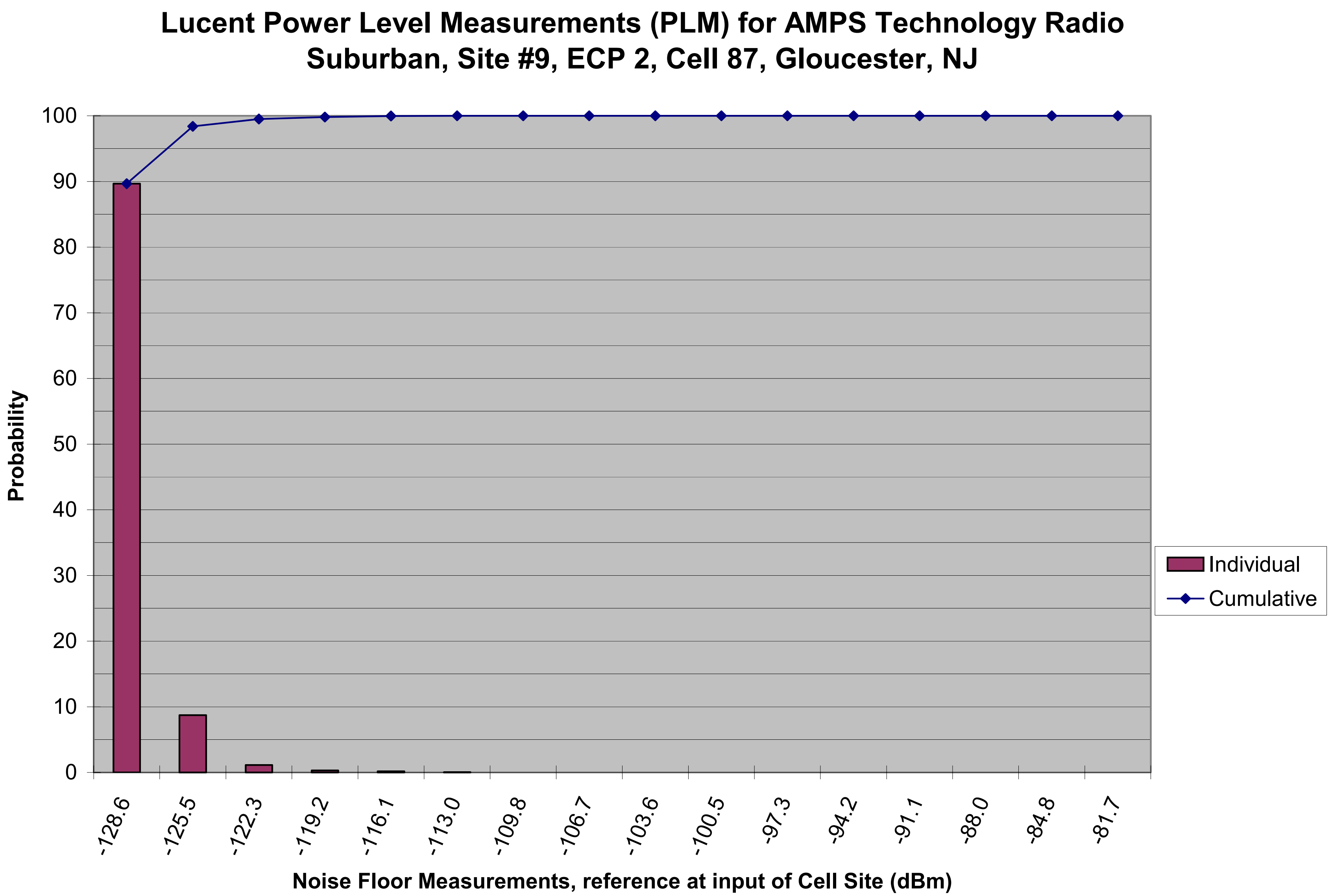

Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Urban, Site #4, ECP 5, Cell 80, Philadelphia, PA
Probability
100
90
80
70
60
50
40
30
20
10
0
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative

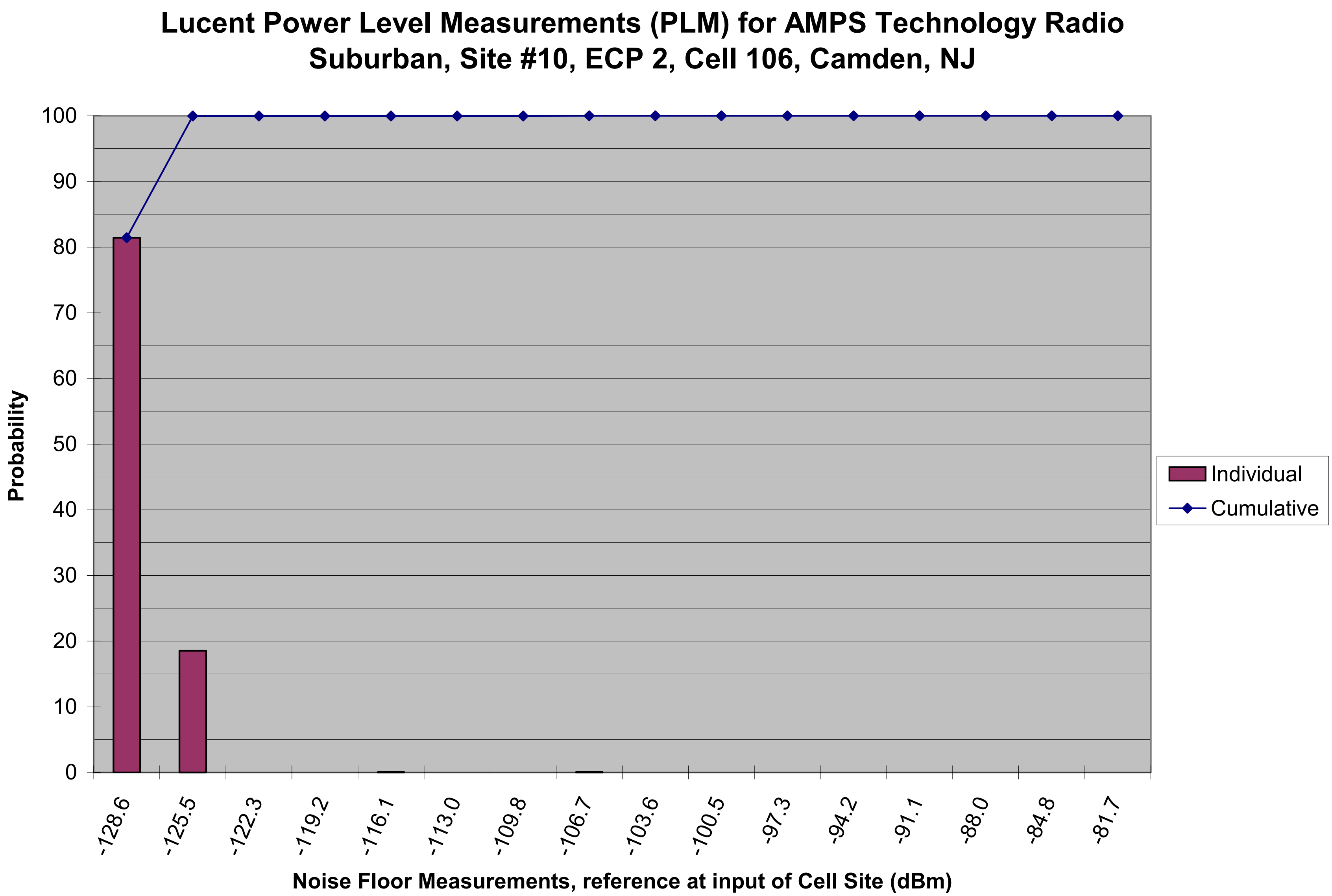

Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Urban, Site #5, ECP 5, Cell 63, Philadelphia, PA
Probability
100
90
80
70
60
50
40
30
20
10
0
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative

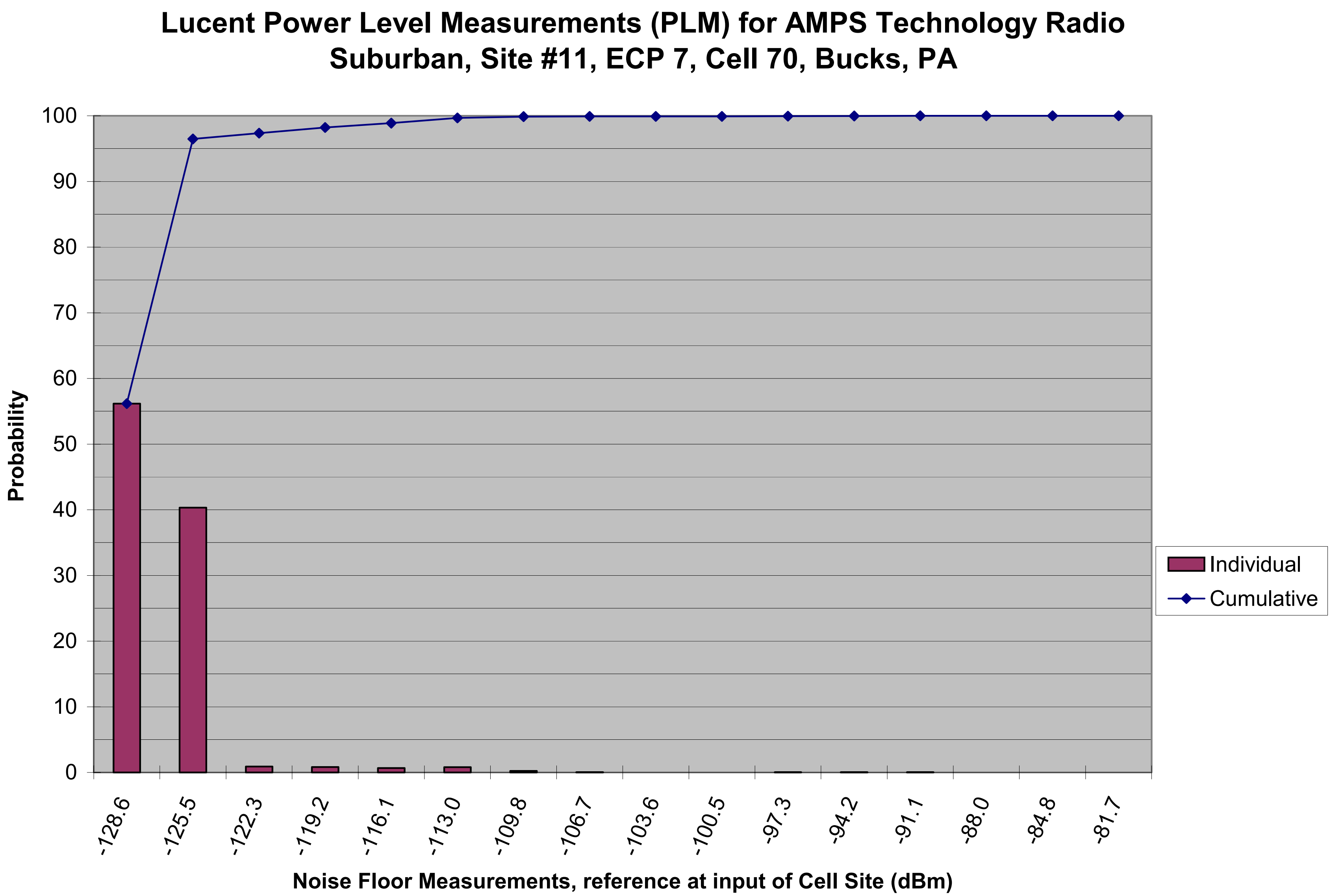

Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Urban, Site #6, ECP 5, Cell 65, Philadelphia, PA
Probability
100
90
80
70
60
50
40
30
20
10
0
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative

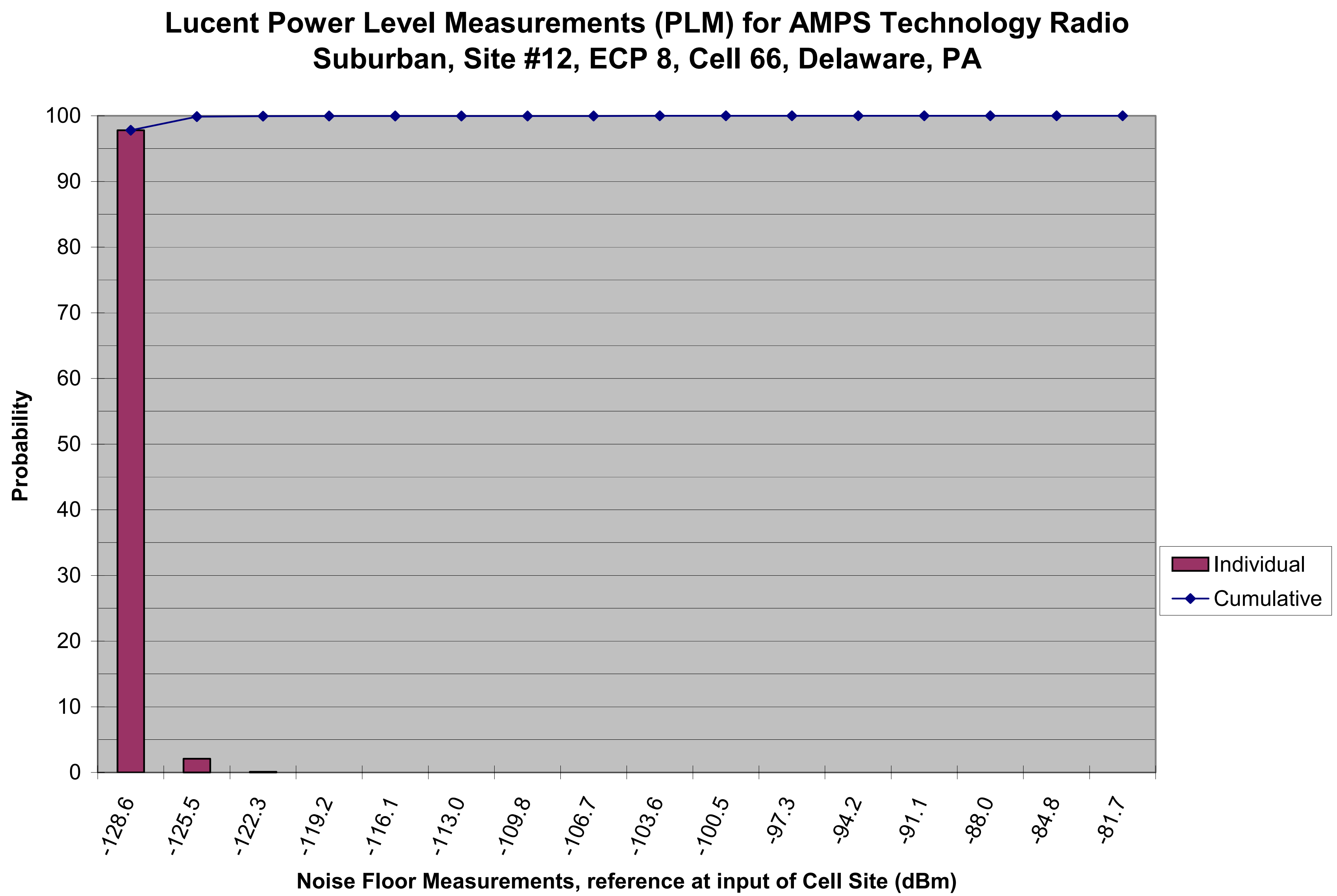

Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Urban, Site #7, ECP 5, Cell 78, Philadelphia, PA
Probability
100
90
80
70
60
50
40
30
20
10
0
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative


Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Urban, Site #8, ECP 5, Cell 57, Philadelphia, PA
Probability
0
10
20
30
40
50
60
70
80
90
100
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative

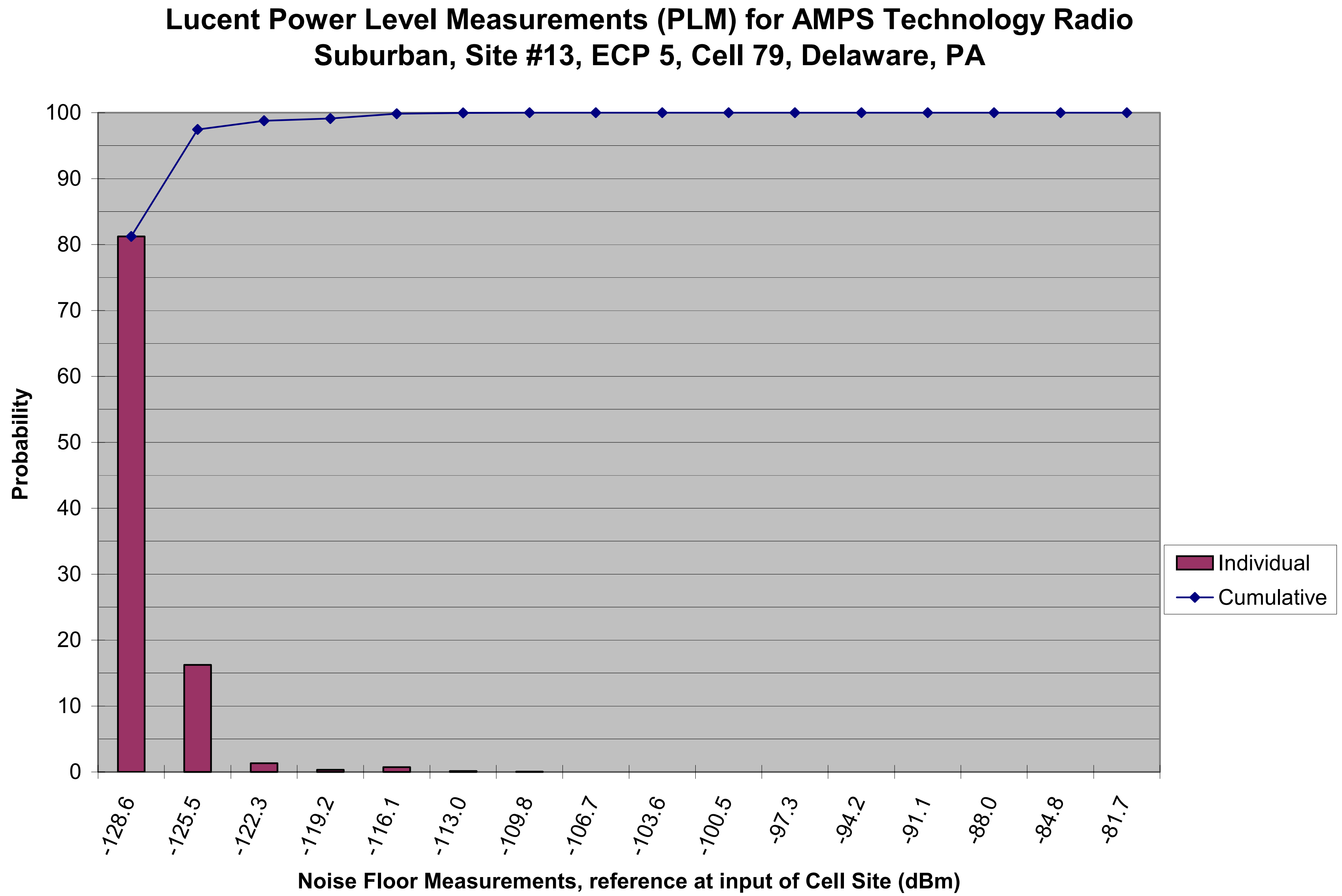

Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Suburban, Site #9, ECP 2, Cell 87, Gloucester, NJ
Probability
100
90
80
70
60
50
40
30
20
10
0
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative

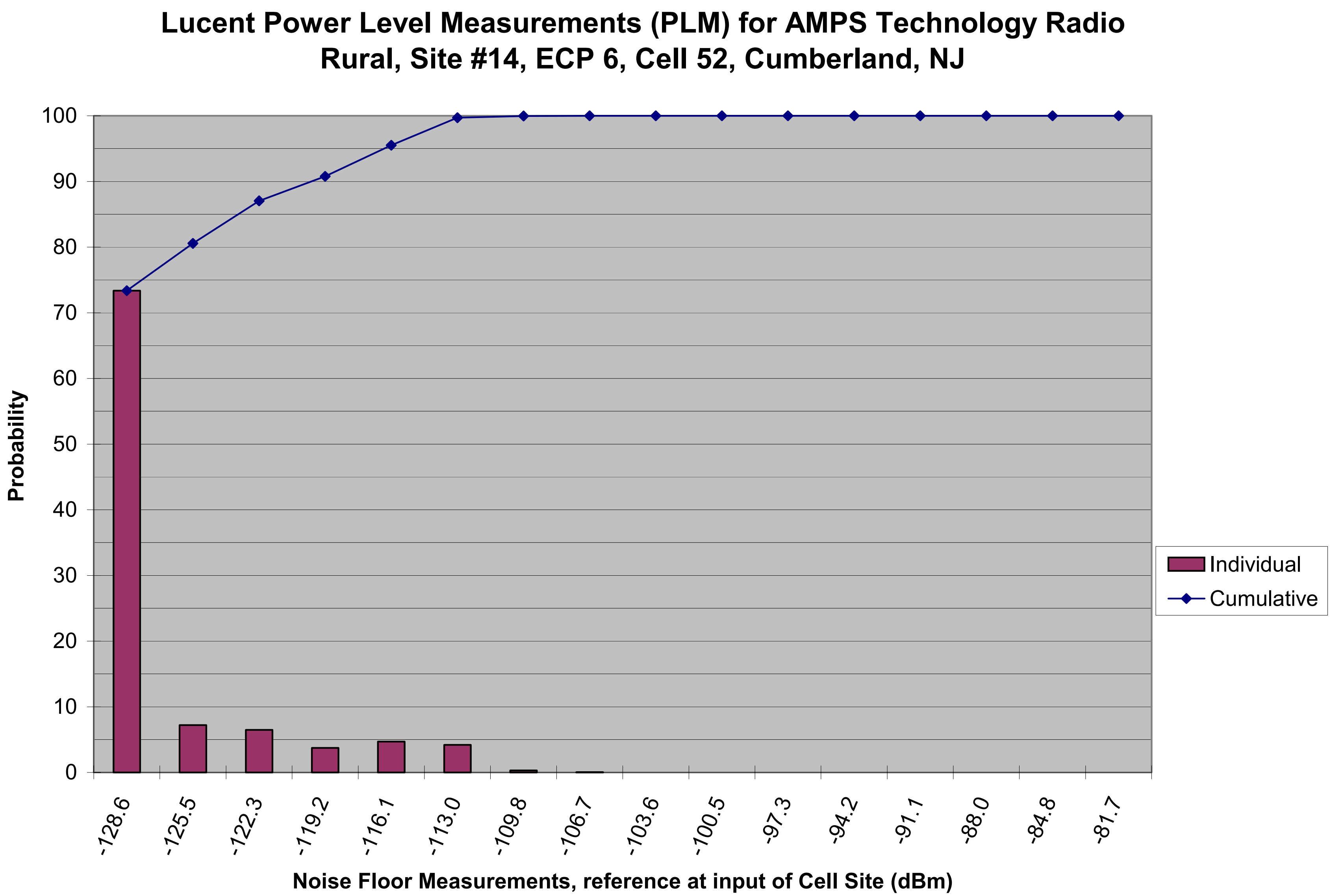

Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Suburban, Site #10, ECP 2, Cell 106, Camden, NJ
Probability
100
90
80
70
60
50
40
30
20
10
0
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative

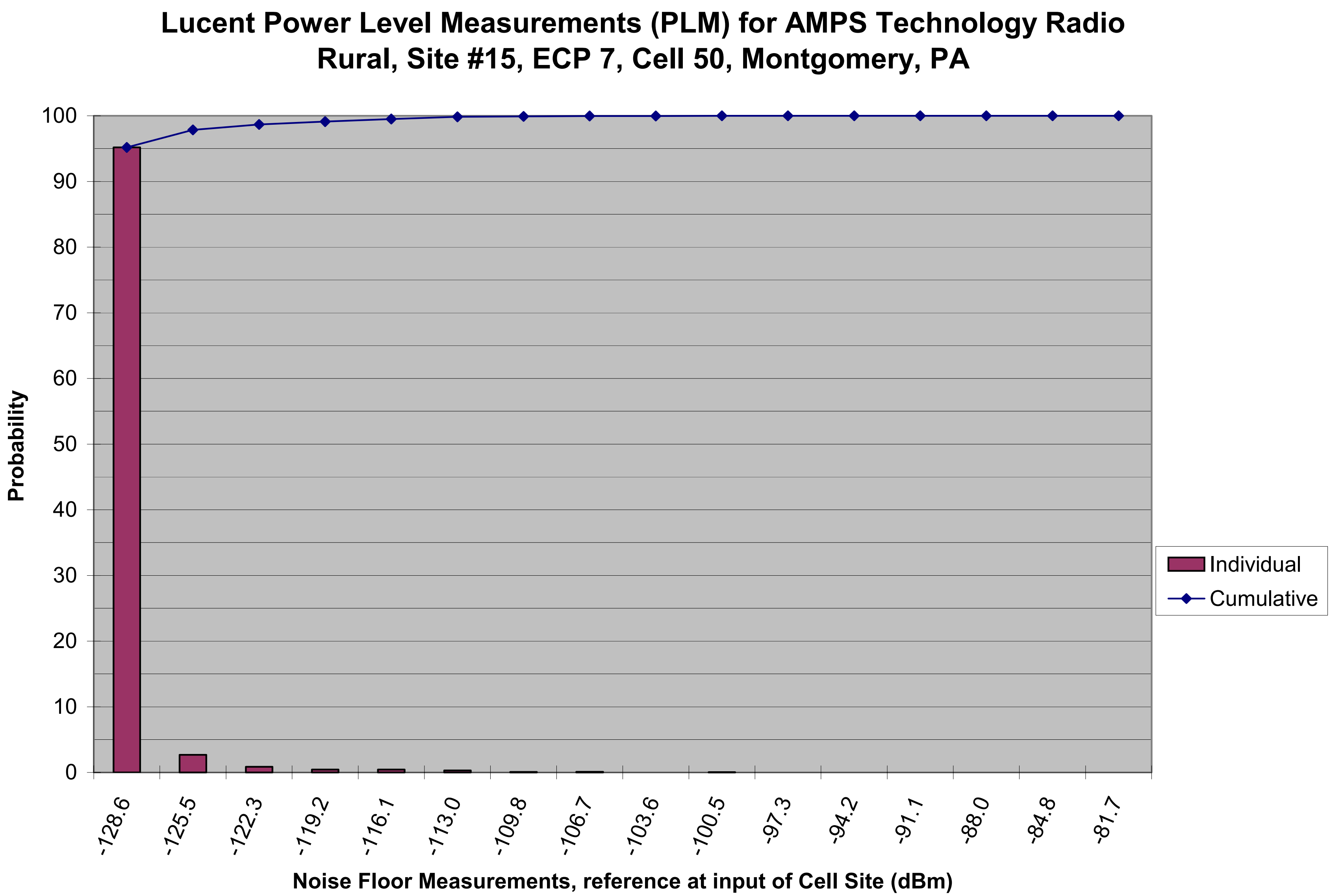

Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Suburban, Site #11, ECP 7, Cell 70, Bucks, PA
Probability
100
90
80
70
60
50
40
30
20
10
0
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative

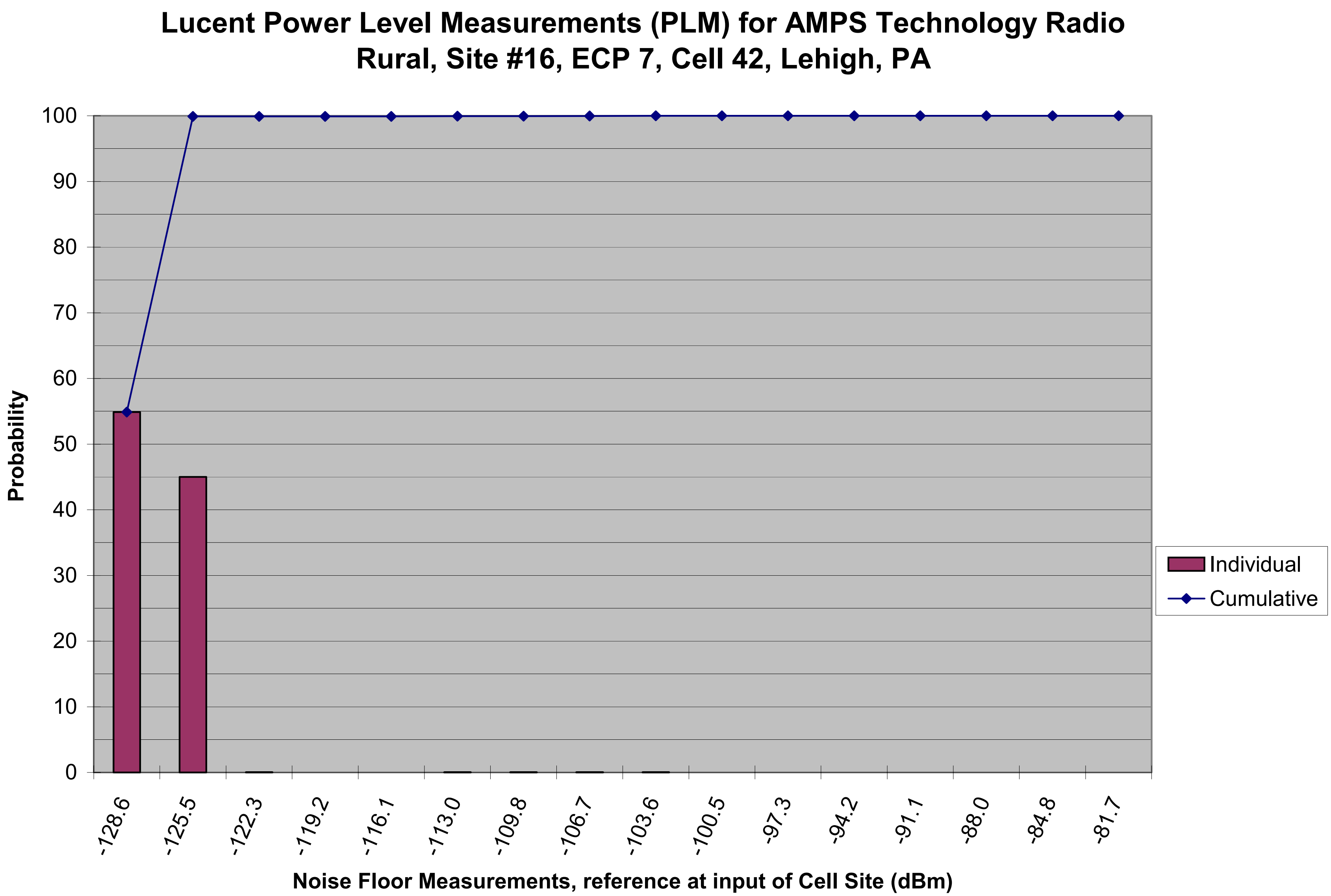


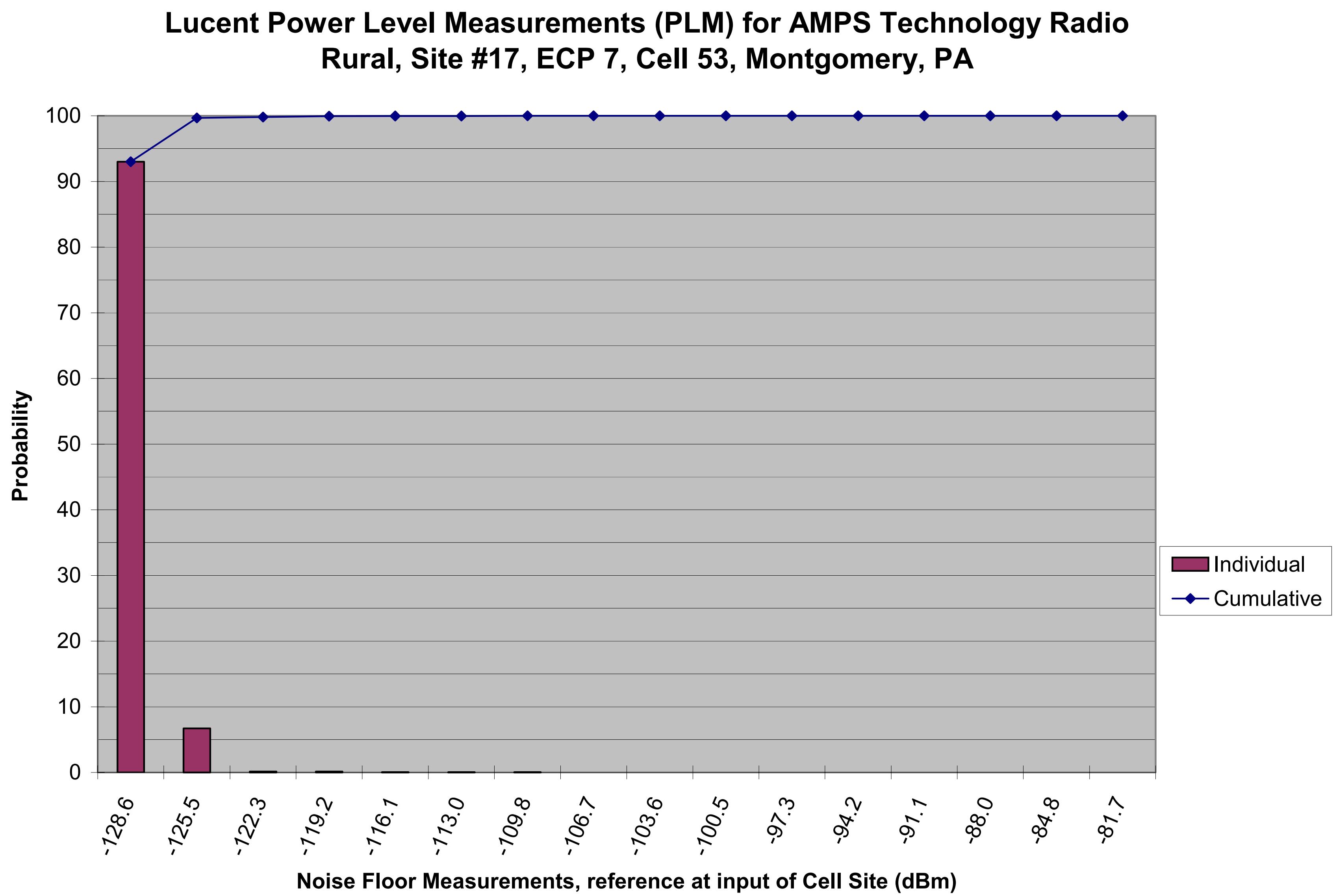
Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Suburban, Site #12, ECP 8, Cell 66, Delaware, PA
Probability
100
90
80
70
60
50
40
30
20
10
0
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative

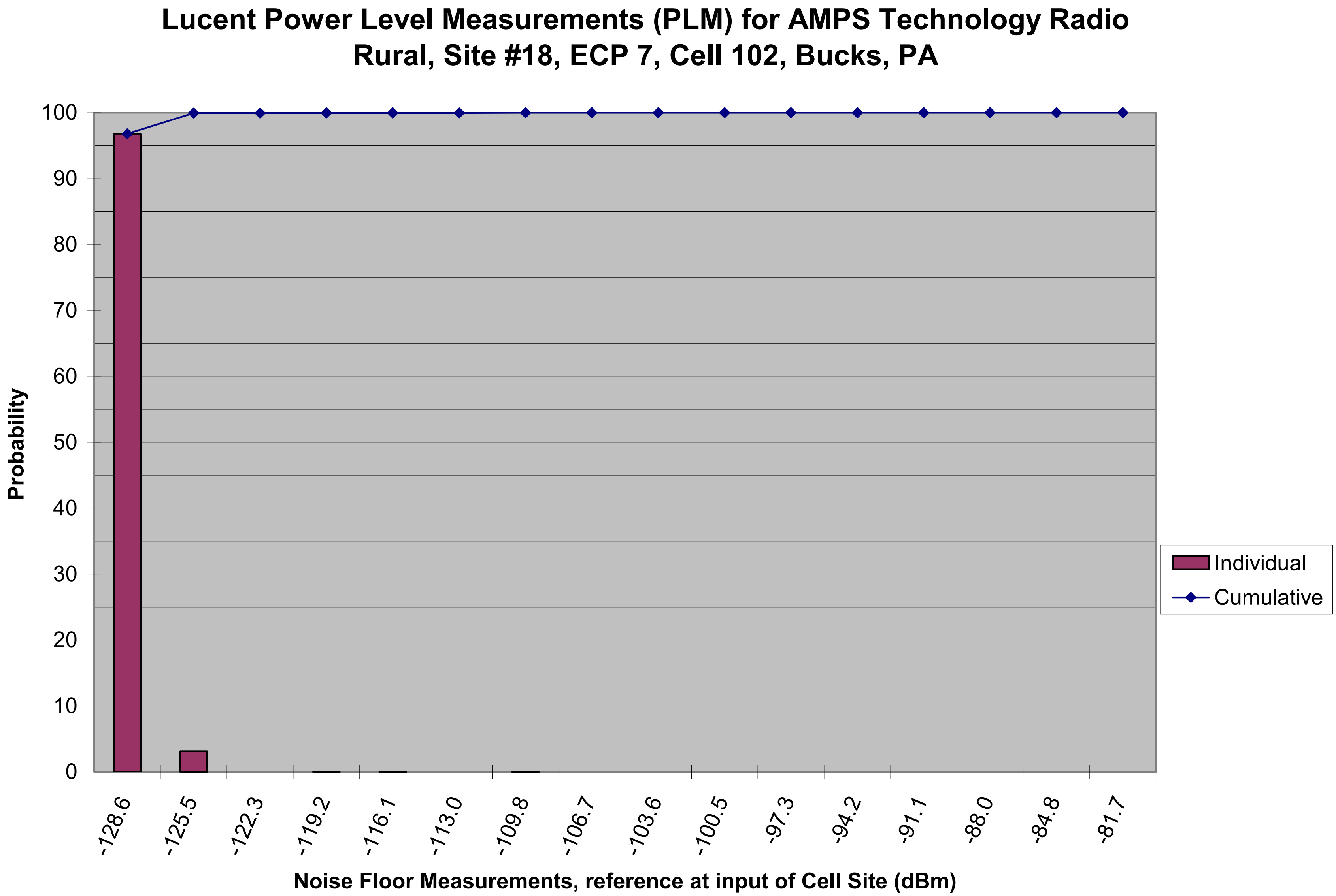

Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Suburban, Site #13, ECP 5, Cell 79, Delaware, PA
Probability
100
90
80
70
60
50
40
30
20
10
0
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative


Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Rural, Site #14, ECP 6, Cell 52, Cumberland, NJ
Probability
0
10
20
30
40
50
60
70
80
90
100
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative


Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Rural, Site #15, ECP 7, Cell 50, Montgomery, PA
Probability
100
90
80
70
60
50
40
30
20
10
0
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative


Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Rural, Site #16, ECP 7, Cell 42, Lehigh, PA
Probability
100
90
80
70
60
50
40
30
20
10
0
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative


Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Rural, Site #17, ECP 7, Cell 53, Montgomery, PA
Probability
100
90
80
70
60
50
40
30
20
10
0
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative


Lucent Power Level Measurements (PLM) for AMPS Technology Radio
Rural, Site #18, ECP 7, Cell 102, Bucks, PA
Probability
100
90
80
70
60
50
40
30
20
10
0
-128.6
-125.5
-122.3
-119.2
-116.1
-113.0
-109.8
-106.7
-103.6
-100.5
-97.3
-94.2
-91.1
-88.0
-84.8
-81.7
Noise Floor Measurements, reference at input of Cell Site (dBm)
Individual
Cumulative

9.18 AirCell Compatibility Test Plan

AirCell Compatibility Test Plan

Sean Haynberg
Director of RF Technologies

David Stern
Vice President

Dominic Villecco
President

June 7, 2002

Table of Contents

1.0 INTRODUCTION & OVERVIEW 2

2.0 AIRCELL COMPATIBILITY TEST PLAN 3

2.1 AIRCELL COMPATIBILITY TEST PLAN - PHASE 1 TESTS 5

2.1.1 TEST 1A - AirCell Airborne Mobile Phone Dynamic Power Control (DPC) Levels 5
2.1.2 TEST 1B - AirCell Airborne Signals Received at Terrestrial Cell Sites 8
2.1.3 Aircraft and AirCell Mobile Antennas 11
2.1.4 Measurements Recorded at Three Terrestrial Cell Sites 12
2.1.5 Test Equipment and Measurements 15

2.2 AIRCELL COMPATIBILITY TEST PLAN - PHASE 2 TESTS 17

2.2.1 TEST 2A - Impact to CDMA Voice Technology (IS-95) 23
2.2.2 TEST 2B - Impact to TDMA Voice Technology (IS-136) 27
2.2.3 TEST 2C - Impact to AMPS Voice Technology (IS-553) 29
2.2.4 Test Equipment and Measurements 30

3.0 TEST MARKET LOCATION & TEST ISSUES 34

3.1 TEST MARKET LOCATION 34

3.2 EQUIPMENT CALIBRATION 34

3.3 PRE-TESTING ISSUES 34

3.4 FUTURE TESTING 34

1.0 INTRODUCTION & OVERVIEW

The objective of this test plan was to determine the compatibility of the AirCell air-to-ground system with terrestrial digital and analog cellular service. The testing involved the use of aircraft and cell site equipment. The testing was conducted in the cellular frequency bands utilizing CDMA, TDMA, and AMPS wireless technologies.

The testing was conducted in the northeastern portion of the United States, specifically within the Philadelphia, New Jersey, and New York markets. These market areas are within range of AirCell's Marlboro, NJ cell site located in central New Jersey.

The test plan was divided into two phases in order to simplify test coordination and measurements being performed for each wireless technology. The first phase of the test plan involved airborne AirCell mobile phone testing. The second phase involved measuring the performance impact to terrestrial cellular service employing the technologies stated above. The testing procedures used in the plan were specifically developed to have the least impact on active cellular customers.

In a cooperative effort with all interested parties, V-COMM prepared this test plan, and also facilitated and coordinated test issues, project management, test execution, post processing of measured data and preparation of the final technical report. Upon submission of the final report, V-COMM, upon request, will present the test results to all parties involved as well as the FCC.

V-COMM's role throughout this project was to serve as an independent third party expert to perform the activities stated above. V-COMM is a wireless telecommunications engineering consulting firm. Our team represents over 50 years of in-depth experience in the wireless telecommunications engineering field. We have provided our expertise to wireless operators in engineering, system design, implementation, expansion and system performance optimization. We have direct experience in all wireless technologies.

2.0 AIRCELL COMPATIBILITY TEST PLAN

This AirCell Compatibility Test Plan was designed to measure AirCell's air-to-ground use of cellular frequencies and its impact to terrestrial-based cellular system performance. Tests, which were developed to determine the effects to terrestrial cellular systems, focused on the cell reverse link (Mobile TX - Base RX) performance metrics to quantify the impact to a cellular system.

The AirCell Compatibility Test Plan was divided into two phases to meet the test objectives. The two phases of the test plan are referred to as Phase 1 and Phase 2. Phase 1 and Phase 2 tests are independent tests. They are described briefly below, and further described in more detail with test descriptions and procedures in the following sections of this document.

Phase 1 Tests - Measure AirCell Airborne Signal Levels
The first phase of the test plan was developed to measure the signal levels received by the serving AirCell site as well as three selected terrestrial cell sites. The test objectives are listed in the next section of this document. This phase was the only test phase that involved actual "in-flight" AirCell mobile phone testing.

Phase 2 Tests - Measure Impact to Terrestrial Cellular System Performance
The second phase was designed to measure the impact to terrestrial cellular system performance when representative AirCell signal levels are introduced, for systems using AMPS, TDMA, and CDMA wireless technologies. The AirCell equivalent signal levels were introduced into the cell site receive path, at the same levels that were measured in Phase 1 tests. Drive test measurements were conducted throughout the terrestrial cell site coverage area, and included forward and reverse link performance metrics. These measurements were compared with the performance of the cell when no AirCell signals were introduced. Analysis of the Phase 2 test results focused on cell site reverse-link (terrestrial mobile TX to cell site RX) performance metrics. The terrestrial cell site reverse link would be the affected link from an AirCell equipped airplane flying within range of the terrestrial cell site.

The benefits of dividing the test plan into two separate phases are listed below. This approach simplifies many testing difficulties, and allows the results to be analyzed in separate tests. This division also enabled us to better understand the AirCell air-to-ground system compatibility with terrestrial digital and analog cellular service.

<u>Benefits of this Two Phase Approach:</u>

1. This will reduce the amount of time that is required to coordinate actual in-flight test scenarios, by collecting a distribution of signal levels from tests at various altitudes and distances. The in-flight tests will need only to be performed once, and not individually for each technology iteration. All cell performance measurements can be made easily afterwards using appropriate injected signal levels, corresponding to those measured in Phase 1 tests.
2. This approach will enable modeling of all scenarios, (best, worst and typical case), since we can control the level of signals that are introduced for each drive test route. (The alternative would be to conduct a test that involved flying & driving, simultaneously. For this case, both the airplane and vehicle are in constant motion and it would be difficult to know whether the worst case scenarios were captured; i.e. with high levels of AirCell signal occurring at the same time that the terrestrial cellular service experiences low signals levels, or whether other scenarios were captured, as well.)
3. This approach will identify the AirCell signal levels that are of concern, as well as a distribution of those levels. With this information, it is easy to focus on the levels that are

above the cellular system's interference tolerance level, and not spend time measuring the effect of signals below this level.

4. If required, the data from the results of Phase 1 tests can be compared to line-of-sight propagation models to predict other scenarios that were not tested, ie. using different antenna patterns, power levels or site configurations.
5. Using the data measured in Phase 1 tests, equivalent signals can be introduced to any cell site, employing any technology, in any market type or under any loading conditions, without involving additional in-flight testing activities.
6. This method allows the testing to be more comprehensive, covering more cases, and provides for reproducible results. This test method will also isolate external and unpredictable events that could adversely affect the validity of compatibility testing.
7. Phase 2 tests involve typical drive routes that are representative of normal customer usage patterns. The drive route received signal level and the background interference noise floor level are matched to typical values measured in-market, prior to testing.
8. Phase 1 & 2 test results can be analyzed to assess the impact to future cellular technologies that will be deployed, such as E911 Phase 2 location determination, 2.5 and 3rd Generation Technology (CDMA2000 1x & 3x, GPRS), smart antenna systems, etc.
9. This method will determine the actual interference tolerance levels for terrestrial cell sites in Phase 2, for all wireless technologies measured.
10. This approach will eliminate the need to re-configure the AirCell cell site and re-program the AirCell mobile from A-band to B-band operation. This also eliminates the need for special temporary FCC waivers and cell site equipment modifications for B-Band operation to test the compatibility to CDMA systems.
11. This will allow us to test the impact to CDMA technology with multiple AirCell signals introduced within the CDMA carrier channel or guard band channels.

2.1 AIRCELL COMPATIBILITY TEST PLAN - PHASE 1 TESTS

The first phase of the test plan involved the airborne use of AirCell's air-to-ground phone system in an aircraft flying a predetermined flight pattern. The objectives of these tests were to measure and record the AirCell signal and airborne mobile power levels that occur during various flight conditions. The Phase 1 flight tests were divided into two separate tests, which are described below, and are referred to as Test 1A and Test 1B.

This phase involved measuring the AirCell airborne signals received by its serving Marlboro AirCell cell site, and also by three selected terrestrial cell sites. Different type and polarity terrestrial antennas were used in the tests to capture and evaluate the AirCell interference levels received by each different configuration. The test plan included Phase 1 flight tests with two different types of aircraft, each utilizing different types of AirCell aircraft/mobile antennas, as listed in section 2.1.3.

The Phase 1 flight tests included 20 days of flight testing; 9 days for the Test 1A flight tests, and 11 days for the Test 1B flight tests. Each day included between 2 and 4 hours of flight time. The total flight time for all Phase 1 tests is between 50 and 60 hours, and the total aircraft distance traveled is over 10,000 air miles. These Phase 1 flight tests generated approximately 28 hours of flight test data with an AirCell call in-progress.

The Phase 1 flight tests for Test 1A occurred on 12/13/00, 12/19/00, 2/20/01, 4/30/01, 5/1/01, 5/2/01, 5/7/01, 5/9/01, and 5/30/01. The Phase 1 flight tests for Test 1B occurred on 11/20/00, 11/22/00, 11/29/00, 12/5/00, 12/6/00, 1/3/01, 2/19/01, 2/27/01, 3/27/01, 6/26/01, and 7/3/01. The flight plans and flight schedules were coordinated with regional FAA and air traffic control centers.

2.1.1 TEST 1A - AirCell Airborne Mobile Phone Dynamic Power Control (DPC) Levels

<u>Test Objectives:</u>

1. To measure the distribution of AirCell mobile DPC levels, for various flight altitudes along typical flight paths.
2. To determine the distance the AirCell airborne mobile unit begins to transmit at maximum power, as well as typical values for each mobile dynamic power level, at various in-flight altitudes.
3. To determine the maximum distance an AirCell airborne mobile unit can maintain a call on its system, at various in-flight altitudes.
4. To measure the distribution of signal levels received by the AirCell cell site, at various in-flight altitudes.
5. To measure supplemental received AirCell signal strength data from selected terrestrial cell sites during testing.

<u>Test Description:</u>

An aircraft equipped with an authorized factory-installed AirCell mobile phone and antenna (as specified by AirCell) will originate a call, while in the vicinity of its serving cell site. The aircraft will maintain the call for as long as possible while flying a straight-line flight path toward and away from its serving AirCell cell site. In addition, the flight path will include a 2nd straight-line parallel path at a distance of approximately 40 miles, to show any variation in results using the broad side of the AirCell mobile antenna pattern. Conceptually, the two parallel paths would form the length of a rectangle. The straight-line flight paths are along typical regional FAA IFR flight routes and must be coordinated with regional FAA airspace specialists and air traffic controllers. The combined result of the intended paths in conjunction with FAA IFR flight routes forms somewhat of a "bow-tie pattern" for this particular test. The map below depicts the "bow-tie" flight patterns performed for this test. Additionally, the flight patterns are always conducted in the same direction, which in this case is the clockwise direction. The AirCell phone and system are operating in its normal operating mode with dynamic power control (DPC), and other cell parameters configured and optimized by AirCell. (Currently, and at the time of testing, AirCell did not configure the Marlboro site for handoff operation.) Each flight test listed below occurs with the aircraft flying the exact same straight-line flight path, and at the altitudes specified below. These altitudes were approved by regional FAA airspace specialists for proper flying altitudes in this part of the country.

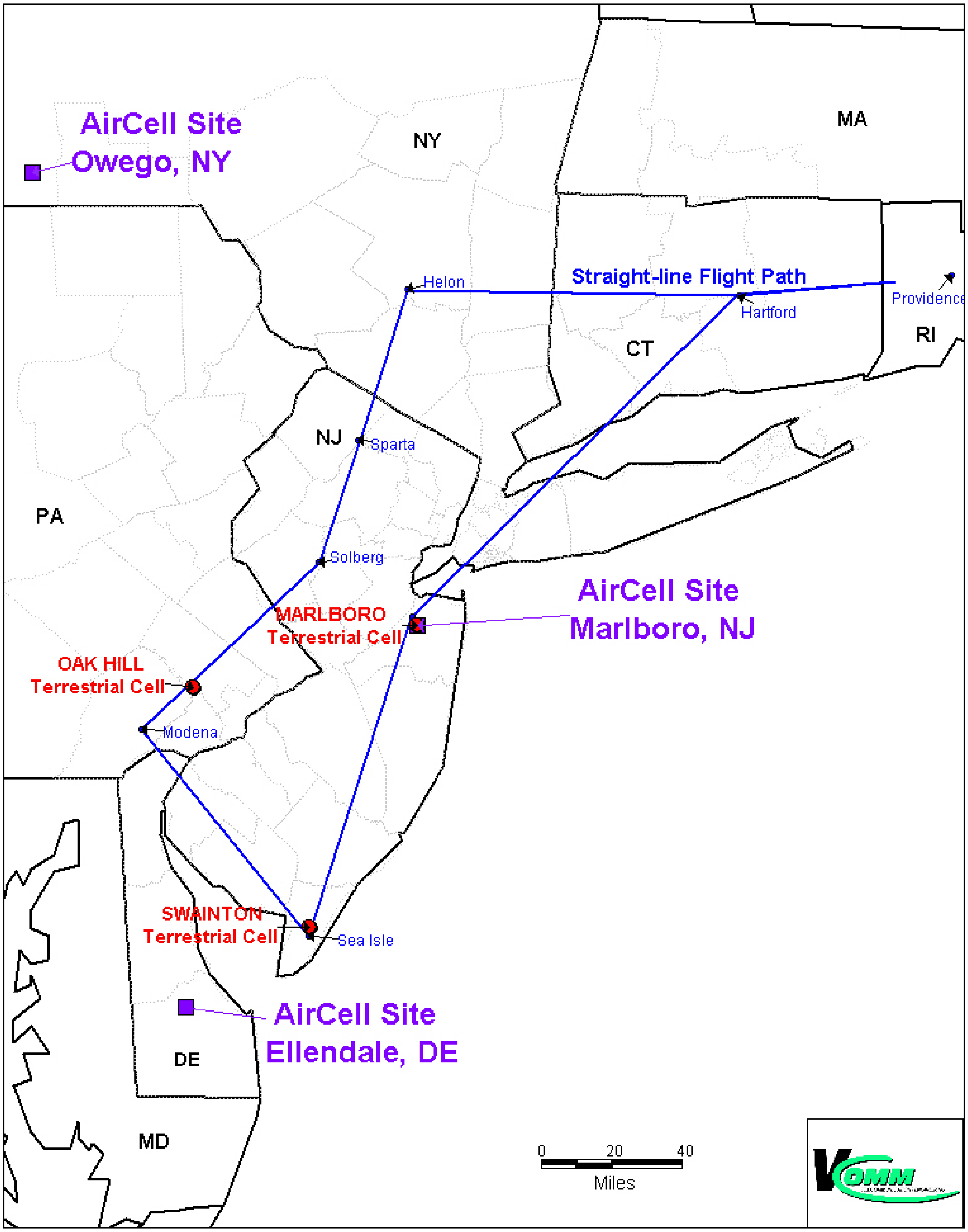
<u>Straight-line Flight Tests with DPC Enabled:</u>

- 4,000 feet (in altitude, AMSL)
- 5,000 feet
- 10,000 feet
- 20,000 feet
- 35,000 feet

The measurements recorded on-board the airplane, and at the AirCell site and terrestrial cell sites during the Phase 1 flight tests are provided in section 2.1.5. In addition, the test equipment and procedures used in the testing, and other test notes are provided in section 2.1.5.

A map of the "straight-line" flight paths used in Phase 1 testing is provided below. These flight paths are used in Phase 1A Tests, the AirCell Mobile Dynamic Power Control (DPC) Levels tests.

AirCell Phase 1 Test - Straight-line Flight Paths



2.1.2 TEST 1B - AirCell Airborne Signals Received at Terrestrial Cell Sites

Test Objectives:

1. To measure the signal levels received at terrestrial cell sites from airborne AirCell mobile units that vary by distance, altitude, cell antenna type and polarization. These measurements occur during flight paths that allow an equal distribution of signals arriving from 360 degrees around the terrestrial cell site's antenna.
2. To measure the path loss of the AirCell airborne signal to the terrestrial cell site. This will enable us to understand and predict values for other antenna configurations and flight patterns.
3. To measure the distribution of received signal levels at the cell site, along with the best case, worst case and typical cases for each flight scenario.
4. To measure the isolation of horizontal, vertical, and slant antenna polarization for terrestrial receive antennas. To determine which antenna types, configuration and polarization offer the best and worst case system isolation.

Test Description:

An aircraft equipped with an authorized factory-installed AirCell mobile phone and antenna (as specified by AirCell) will originate and maintain a call, while in the vicinity of designated co-channel terrestrial cellular system cell sites. The aircraft will fly a circular or arc flight pattern around the AirCell & terrestrial Marlboro cell site, maintaining the specified altitude and arc distances from the Marlboro cell site, for each flight test listed below. The AirCell mobile phone will transmit at a fixed maximum power level during these tests using the AirCell mobile DPC level 2, which corresponds to the FCC maximum power limit of 75 milliwatts for AirCell mobile phones. All other AirCell system parameters and configurations are operating according to AirCell specifications. Cell site parameters accomplish this test configuration with mobile Dynamic Power Control State disabled and Voice Mobile Attenuation Code equal to 2, which corresponds to the 75 milliwatt FCC mobile power limit.

Testing with the mobile transmit power fixed to its maximum level is essential for a variety of reasons, which are further explained in the final report. One reason is that is allows us to isolate and measure the signal levels received from airplanes with different orientations to the victim cell site, without power fluctuations affecting the results. This allows us to measure and analyze the impact of airplane orientation (altitude, distance and angle from terrestrial site) to the signal levels received at the terrestrial site. AirCell's DPC function is independent of the distance to the victim terrestrial cell site; it is dependent on the distance to its serving AirCell site. AirCell's DPC level and the received signal path loss to the victim terrestrial site are two independent variables. By measuring and analyzing these affects in separate tests, it allows better understanding of the results. It also allows other flight paths to be analyzed with the affects of DPC included. For these reasons, the DPC affects are measured separately under the 1A tests.

The arc pattern flight tests (around the AirCell and co-located terrestrial Marlboro, NJ cell site) are described below. Flight tests were performed at each altitude and arc pattern, as listed in the tables below. The altitudes included in these flight tests are listed below.

Arc Pattern Flight Tests with DPC Disabled (Fixed Max Power, DPC Level 2):

- 2,000 feet (AMSL)
- 5,000 feet
- 10,000 feet
- 20,000 feet
- 35,000 feet

During each flight test at the altitudes specified above, the flight path includes the following arc patterns, around the terrestrial Marlboro cell site. With these flight paths, the signals received at the terrestrial Marlboro site will be proportionately distributed and measured over 360 degrees around the terrestrial cell antennas. In addition, the airplane will be flying toward and away from the terrestrial Marlboro site when traversing between arc patterns. Again, testing with the AirCell mobile transmitting at its fixed maximum power, allows us to measure the impact the airplane orientation (altitude, distance and angle from terrestrial site) has on the signal levels received at the terrestrial site.

<u>Arc Pattern Flight Tests - Radius of Arc</u>

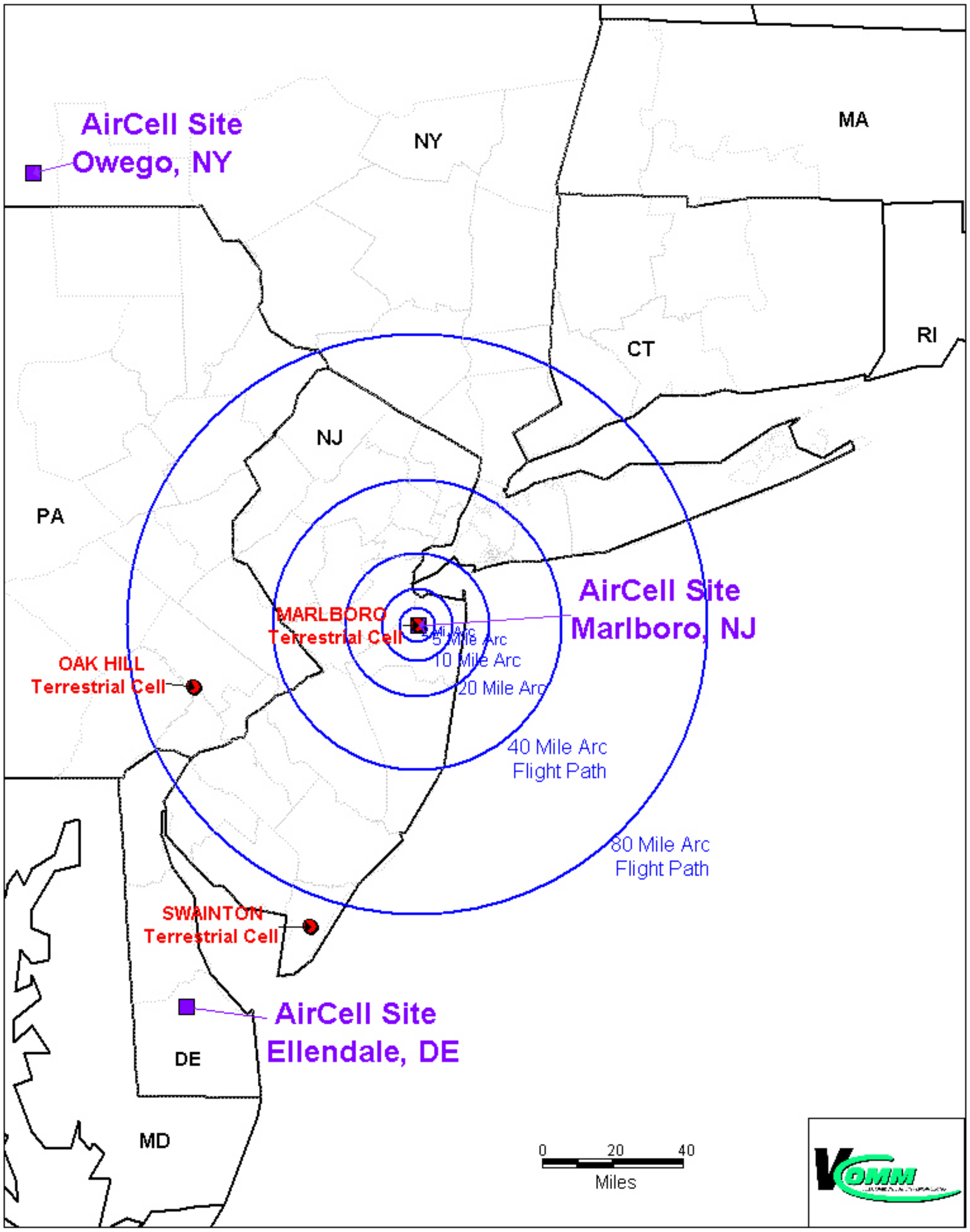
- 2 mile radius
- 5 mile radius
- 10 mile radius
- 20 mile radius
- 40 mile radius
- 80 mile radius (All altitudes, except the 2,000 ft)

(The lowest altitude flight test represents low flying aircraft within 40 miles of the serving AirCell site. This low elevation data is also useful for path analyses of aircraft landing and take-off, and for terrestrial cell sites on high ground elevations.)

The test equipment, measurements and procedures used for these Phase 1 flight tests are provided in section 2.1.5.

A map of the arc pattern flight paths, used in these Phase 1 tests with DPC disabled, is provided below. These flight paths are used to measure the path loss and received signal strength of the AirCell airborne signals, as measured at the terrestrial cell sites.

AirCell Phase 1 Test - Circular Flight Paths



2.1.3 Aircraft and AirCell Mobile Antennas

The test plan includes aircraft flight tests with two different types of AirCell mobile antennas. Provided in the pictures below, are the aircraft and AirCell mobile antennas, used in Phase 1 tests. Both AirCell mobile antennas are horizontally polarized antennas that are specified, mounted, and installed in the aircraft by an authorized AirCell installation facility. The flight tests at lower altitudes (10,000 feet and lower) use the Twin-Engine Piston type Aircraft, and at higher altitudes use the Jet Engine type aircraft. The jet engine aircraft has a high horizontal stabilizer, and uses the AirCell belly-mounted antenna. The piston engine aircraft has a lower horizontal stabilizer, and uses the AirCell VOR style antenna on both sides of the vertical stabilizer. The aircraft and AirCell mobile antennas used in the Phase 1 tests are pictured below. The piston twin engine type aircraft is a Piper Navajo, and the jet engine type aircraft are a Learjet 35 and King Air B200.

Pictures 2.1.3-A - Jet Aircraft and Belly-mounted AirCell Antenna (High Altitude Flight Tests)

Pictures 2.1.3-B - Piston Aircraft and VOR style AirCell Antenna (Low Altitude Flight Tests)

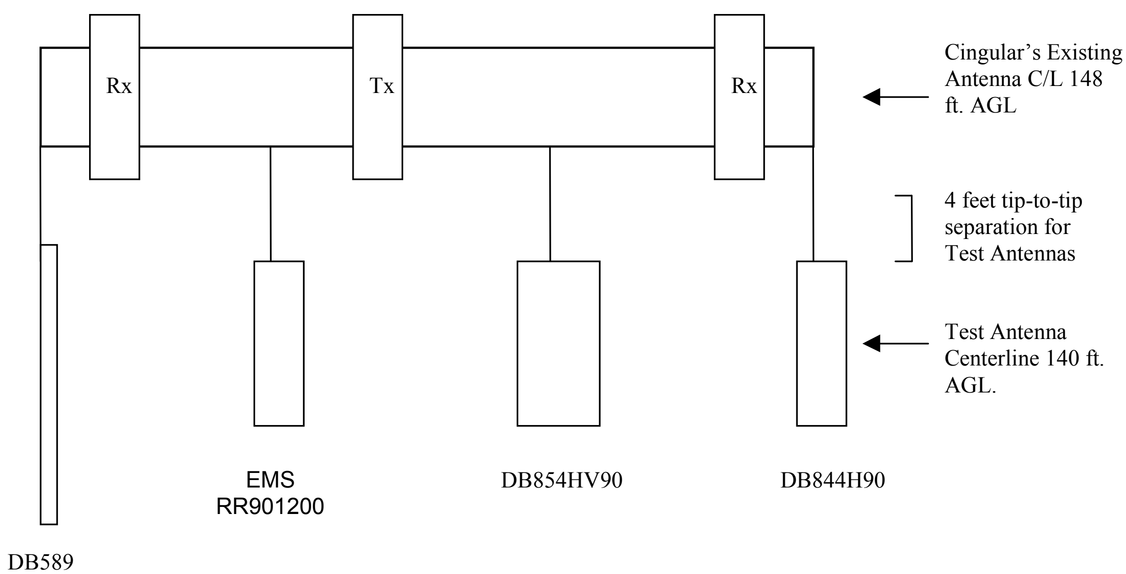
2.1.4 Measurements Recorded at Three Terrestrial Cell Sites

During Phase 1 flight testing, cell site receive path signal strength measurements are recorded at three terrestrial cell sites. These measurements are recorded within the receive path of the terrestrial cell sites, and are referenced to the cell site hatch plate. These measurements are made simultaneously at seven different terrestrial receivers. Grayson test receivers are used to record the received signal measurements and verify the proper SAT. Four receivers are connected to four test antennas installed at the co-located AirCell Marlboro & terrestrial cell site. The four test antennas are installed on the tower platform, facing 270 degrees from true north, and at approximately 140 feet above ground level. Three other receivers are connected to two other terrestrial cell sites. The configuration of the two other terrestrial cell sites used in the testing are as they exist in the cellular A-band market. One terrestrial cell site is the Oak Hill Cell Site, in King of Prussia, PA located approximately 65 miles from the Marlboro AirCell site, and the other is the Swainton, NJ cell site located approximately 88 miles from the Marlboro AirCell site. Measurements at the Oak Hill cell site include its alpha (sector 1) receive antenna path, and the Swainton cell site include its alpha and gamma (sector 1 & 3) receive antenna paths. These antenna azimuths of sector 1 & 3, are 30 and 270 degrees, respectively, from true north reference. The Oak Hill and Swainton terrestrial cell sites use typical panel directional antennas (vertically polarized) with an antenna gain of 12 dBd, and 90 degree horizontal beam width. The Oak Hill Cell Site antenna center-line is approximately 50 feet above ground level, and the Swainton Cell Site antenna center-line is approximately 180 feet above ground level.

<u>Four Cellular Test Antennas Installed at Marlboro Terrestrial Cell Site:</u>

1. Omni Antenna -- (9 dBd Gain), Decibel Products DB589, with 8 deg. vertical beamwidth (utilizing platform mount to minimize tower shadowing). This antenna is referred to as OMNI test antenna in the report.
2. Vertical-Pole -- Sector Panel Antenna (12 dBd Gain), Decibel Products DB844H90, with 15 deg. vertical beamwidth and 90 deg. horizontal beamwidth. This antenna is referred to as V-POL test antenna in the report.
3. Horizontal-Pole -- H/V Polar Diversity Sector Antenna (11.5 dBd Gain), Decibel Products DB854HV90-SX, with 15 deg. vertical beamwidth, and 90 deg. horizontal beamwidth. This antenna is referred to as H-POL test antenna in the report.
4. Slant 45° -- SL45 Polar Diversity Sector Antenna (11.7 dBd Gain), EMS RR90-12 with 14.6 deg. vertical beam width and 90 deg. horizontal beam width. This antenna is referred to as SL45 test antenna in the report.

The sector panel-type cellular antennas (listed above as test antenna #2, #3 & #4) are oriented side-by-side with a pointing azimuth of 270 degrees from true north and 140 feet height on the tower, for easy comparisons of received signal levels. The omni-directional antenna is also mounted at the same height and location on the tower, allowing the data to be directly compared. The V-POL test antenna (#2 above) has antenna specifications very similar to the Oak Hill and Swainton terrestrial cell sites. Below is a diagram and pictures of the test antenna arrangement, which is mounted below Cingular's existing base station antenna array for its gamma sector. These antennas are collocated with AirCell's base station antennas at the Marlboro site.




The four test antennas (above) were selected to be representative of the different types of antennas that exist in cellular networks today. The test results will allow us to compare the AirCell signal strengths received at the four different type and polarity antennas listed above. The horizontally polarized terrestrial test antenna should receive the highest signal strength, since the AirCell mobile is transmitting with a horizontally polarized antenna.

The vertically polarized panel-type sector antenna is the most common type of antenna in cellular networks today. However, the dual polarity diversity antennas, H/V and Slant 45 degree antennas, are becoming more popular in suburban, urban and dense urban markets with less cell site zoning, construction and site acquisition issues. For example, Cingular Wireless plans to installation approximately 45,000 of the dual polarity type antennas over the next two-year period, as approved by an FCC waiver.

For test purposes, frequency clearing is required for the radio channel used by the airborne AirCell call during the flight tests. It must be cleared away from the area surrounding of the three terrestrial cell site areas where the measurements are performed. This will prevent the possibility of other terrestrial signals from corrupting the test data collected. The co-channel and adjacent channels are cleared for a minimum distance of 50 miles and 30 miles, respectively, away from the three terrestrial cell sites that are collecting measurements during the flight tests.

Grayson test equipment receivers are used to record the AirCell signals received at the terrestrial cell sites. In addition, the SAT frequency will be recorded at each receiver to verify the proper SAT is received, which is SAT 1 for the AirCell Marlboro site. The receivers will measure the AirCell signal strength and verify the proper SAT, at the four test antennas at Marlboro, and the Oak Hill & Swainton terrestrial cell sites. All Grayson receiver test equipment signal measurement accuracy was calibrated and verified before and after testing. The receiver's signal measurement accuracy was verified with a calibrated HP8591 spectrum analyzer for all seven Grayson receivers. The measurement accuracy of the seven Grayson receivers used in the testing are within 1 dB, which is within the equipment's measurement tolerance specification.

2.1.5 Test Equipment and Measurements

The following test equipment & tools, measurements and procedures are used on-board the airplane, and at the AirCell and terrestrial cell sites during the Phase 1 flight tests.

Test Equipment & Tools:

1. Grayson GMR200 receiver test equipment to measure the received signal level (using linear power averaging over 1 second intervals)
2. Lucent RF Call Trace to record the AirCell mobile DPC level, and the signal level referenced to the AirCell radio (using 2 second polling interval)
3. Lucent Power Level Measurements (PLM)
4. Spectrum Analyzer, with filter and low noise figure LNA
5. Computer-based GPS receiver

Record Measurements:

1. GPS location of the Airplane
2. Received Signal Power at the AirCell serving site and the victim terrestrial cells
3. Received Signal SAT at the AirCell serving site and the victim terrestrial cells
4. AirCell Mobile Transmit Dynamic Power Level (DPC)
5. Time stamp with each measurement device

Test Procedures & Test Notes:

1. Prior to performing measurements in the field, the test equipment was calibrated, and checked & verified for the specific channel used during flight tests. The Grayson receivers signal measurement accuracy were within specification, which is within 1 dB.
2. Normal voice conversations on the cellular reverse-link channel are used during flight tests with a voice activity of between 25% to 40%.
3. GPS antenna is located in the airplane cockpit window, for airplane GPS readings.
4. The time stamp field will allow us to match the Airplane GPS readings with the RSSI readings measured at the terrestrial cell sites, and the AirCell mobile DPC levels recorded in the RF Trace data. The time of each device was synchronized prior to each flight test.
5. All test data is post-processed and merged using the time stamp field. When the RSSI readings (1 second data) are merged with the RF Trace (2 second data), the resultant data has 2 second intervals.
6. The insertion loss of the test coaxial cables used in the testing, and the offset to the cell site receive path connection point, are measured with calibrated test equipment and recorded.
7. All signal levels in the final report will be referenced to the cell site hatch plate. This reference is the antenna side connector, of the cell site jumper cable used to connect the cell site equipment to the transmission line. Signal units are in dBm (decibels, ref. to 1 milliwatt).
8. All distances in the test plan and final test report will reference statue miles.

For all drive tests, the localized test parameters, test environment, and test conditions in the field were maintained as consistent as possible, to ensure repeatable drive test results. The same exact drive route and roads were utilized in all drive tests. Other parameters and test conditions that were consistent across drive tests include:

1. Drive route - The drive route was designed to be consistent for all tests. Almost all turns were designed to be right turns, so that stopping at a stop light would not delay the drive tests. If there was a delay longer than a few moments during a particular drive route, the test engineers "paused" the data collection equipment, and continued data collection when the drive resumed. The exact roads were driven start to end. The time of the drive route was extremely consistent, with some drives ending within seconds of each other.

2. System Loading Condition - The system loading was designed to be similar for all drive tests and representative of normal day-time operation. These drive tests were conducted between the hours of 9 AM to 3 PM on normal business days. System traffic levels were reviewed and the system loading was consistent across the drive tests for this day-time period.
3. Interference - Injected interference at the terrestrial cell site was input at a fixed steady-state level for each drive test, and was verified before each day of testing.
4. Foliage Effects - All drive tests were conducted in the same season of the year (during the winter season) with the leaves off the trees, for direct comparison of the test results.
5. Drive Test Equipment - The exact same drive test equipment, cell phones, drive test vehicle, and test procedures were used for all drive tests, for direct comparison of the test results.

2.2 AIRCELL COMPATIBILITY TEST PLAN - PHASE 2 TESTS

The objective of the second phase of the test plan is to measure the performance impact to terrestrial cellular systems when AirCell equivalent signal levels are injected into a cell site's receive path, for systems utilizing CDMA (IS-95), TDMA (IS-136), and AMPS (IS-553) wireless technologies. AirCell equivalent signal levels will be injected into the cell site receive path, at the same levels that were measured in Phase 1 tests. This test will capture and quantify any performance impact to the cellular system. This simulates an AirCell equipped airplane in-use and within range of the terrestrial cell site, using the signal levels measured from Phase 1 tests.

The test objectives and test methods used in Phase 2 tests are listed below.

<u>Phase 2 Test Objectives:</u>

1. To measure the terrestrial cellular system performance before and after AirCell signals are introduced, using the measured AirCell signal levels from Phase 1 tests. To include tests on terrestrial cellular sites operating with CDMA, TDMA, and AMPS technologies.
2. To perform terrestrial system performance measurements along drive routes that represents normal customer usage patterns within a cell's coverage area.
3. To measure and analyze any impact to the performance of the terrestrial system. This includes the impact to coverage, capacity, voice quality, and quality of service (QOS).
4. To measure the cell site ambient and operating noise floor level, during normal system operating conditions.

<u>Phase 2 Test Methods:</u>

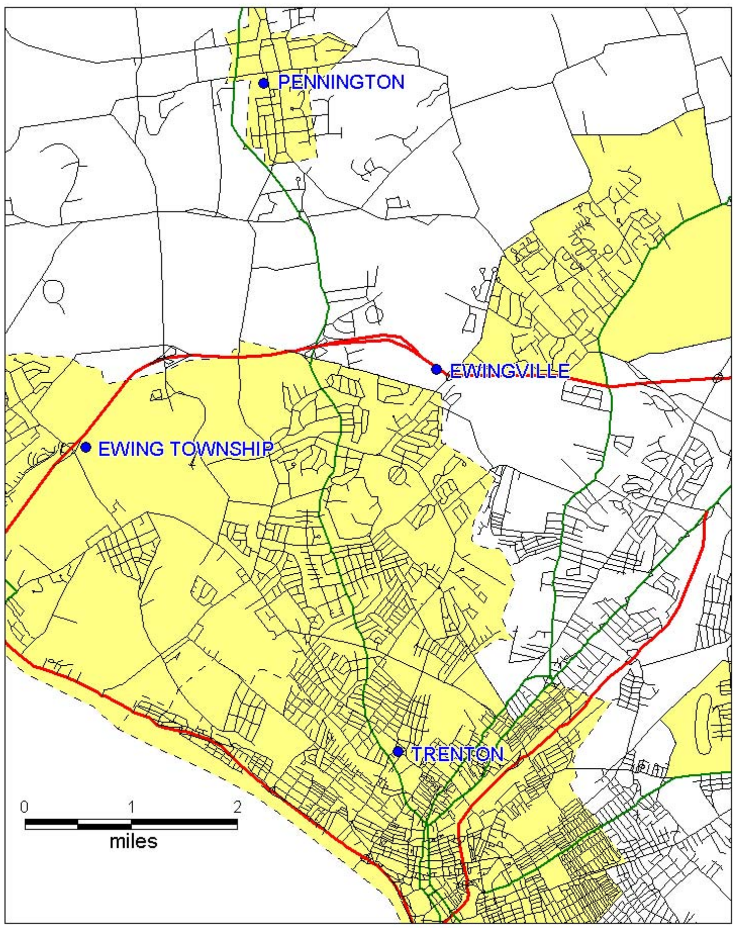
1. Testing with an actual cell site that exists in the field, in its normal operating and configured mode, with normal system loading, and actual market interference conditions, for a typical suburban cell site. These cell site and market conditions are present during Phase 2 tests.
2. Drive testing in the market, within the cell site's actual coverage area, matching signal levels from actual customers.
3. Testing during actual day-time noise floor conditions. All cell site antennas and receive path systems are connected and configured normally. This allows the actual day-time operating noise floor conditions that exist in-market to be realized for testing.

The cell site and market conditions used in the Phase 2 tests are actual conditions that exist in the particular market. Therefore we are using the "real world" and "actual" cell site received signal levels, operating cell site noise floor levels, cell site configurations, and market conditions. This ensures the results are representative of actual cell sites within the market.

A typical suburban cell site is selected for Phase 2 tests. It is intended to be representative of an average study case, within the market types Dense Urban, Urban, Suburban, Rural and Quiet Rural. It is not intended to represent the worst or best case site, nor the worst or best case suburban site. It is intended to represent an average or typical suburban site, which exists in the northeast.

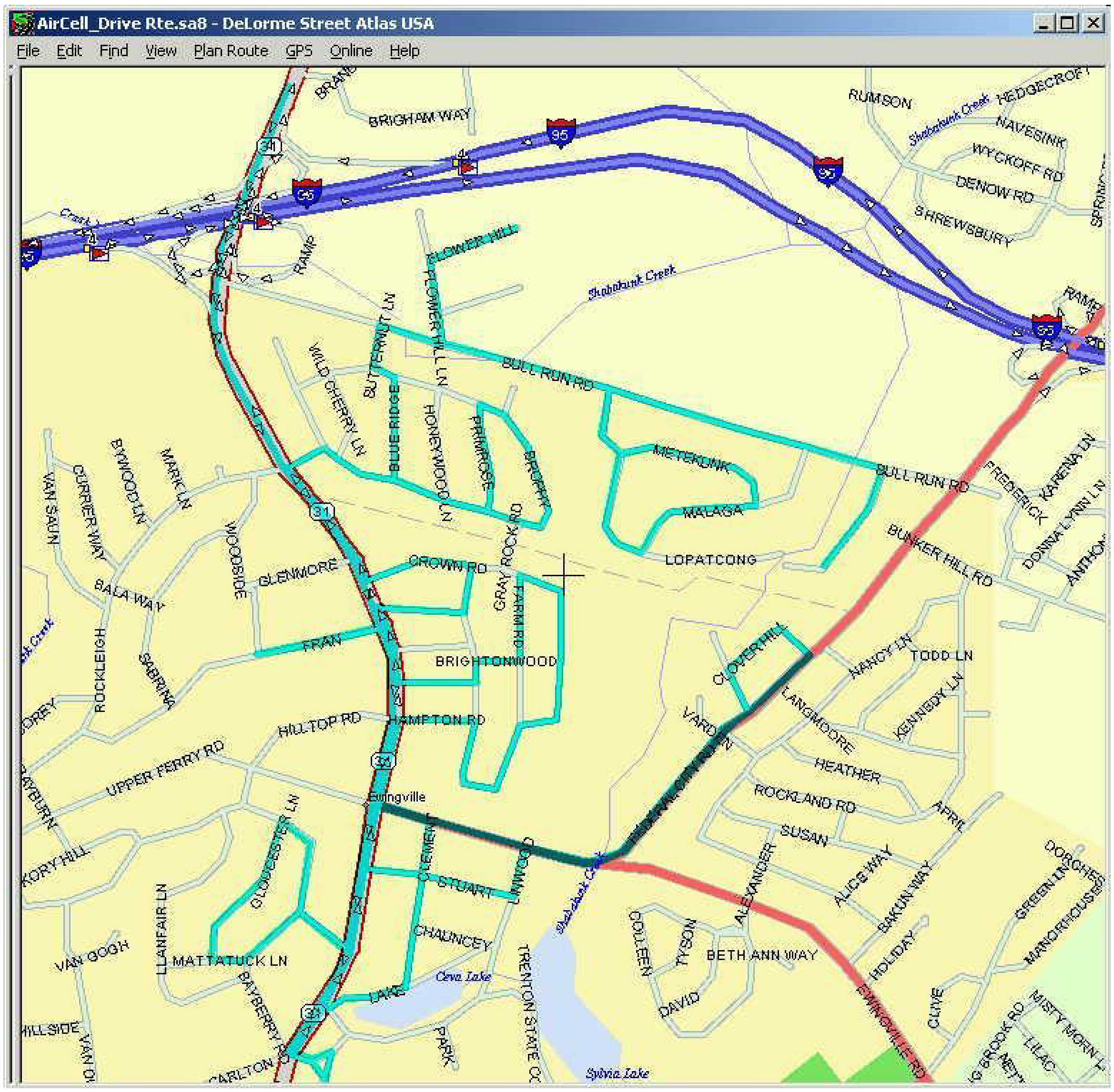
Further, the selected terrestrial cell site is representative of a typical suburban cell site within the New Jersey and Philadelphia market areas that would be found within the coverage footprint of the AirCell Marlboro cell site. The signal and noise floor levels for numerous cell sites in these market areas were analyzed to determine a typical suburban cell site for Phase 2 testing. The suburban cell site used in Phase 2 testing is the Ewingville cell site, located within the Trenton, NJ MSA market area, in Mercer County, NJ. The area surrounding the Ewingville site is a typical suburban setting with houses, parks, trees and single-story commercial buildings along major roads. The site is located just south of Interstate 95, approximately 3-4 miles north of Trenton, and approximately 6 miles southwest of Princeton, NJ. The cell site coverage area extends to a radius of approximately 1.5 miles, which is typical for suburban cell sites in this area. This cell site is a co-located site for Verizon Wireless (B-band carrier) and Cingular Wireless (A-band carrier). In addition, the four surrounding cell sites, in the north, south, east and west directions, are also co-located sites with both Verizon and Cingular as co-tenants. Provided below, is a map depicting the Phase 2 Test Area and Surrounding Cell Sites. Both cellular carriers use Lucent cell site equipment in this market. These cellular networks employ 3-sectored cell sites, with nominal horizontal beam-width antenna patterns of 90 degrees and sector antenna azimuths of approximately 10, 130 & 250 (alpha, beta and gamma) degrees from true north reference. Both carriers have their antenna systems between 90-115 feet above ground level for three sites: Ewingville, Ewing and Pennington; and approximately 150 feet above ground level for the Trenton cell. With similar network configurations, the test cell site's coverage area is extremely similar for both carriers in this area. This works very well for test purposes, and it allows the Phase 2 results to be compared for the different wireless technologies. During Phase 2 tests, the cell site is operating and configured in its normal mode. This allows the performance impact of the cell site to be measured and evaluated for the different Phase 2 signal injection tests.

Phase 2 Test Area and Surrounding Cell Sites



The cell site's gamma sector (and associated coverage area) is used for Phase 2 drive testing. The drive route is selected to cover the roads within the coverage area of this sector, and match the distribution of typical customer signal levels received by the terrestrial cell site. The drive route was selected to cover an even distribution of roads within this sector's coverage area. The drive route also covers roads that are within 0.2 miles to 1.5 miles from the terrestrial test cell site, or out to the edge of this sector's coverage area. The duration of the drive route from beginning to the end is approximately 40 to 42 minutes, with the test vehicle driving consistent speeds for each test. The total distance of the drive route from beginning to the end is approximately 13 miles. Provided below, is a map of the drive route used in Phase 2 tests, with roads highlighted in light blue.

Phase 2 Test - Drive Route Map



The Phase 2 drive tests occur during normal business operation between the hours of 9:00 am and 3:00 pm. Phase 2 drive tests were not measured in the busy hour periods of the cell site, to avoid causing interference to the cellular system in its busiest hours. Testing in day-time, non-busy hour periods, is more representative of typical or average case scenarios, which is the intention of these Phase 2 tests. Testing within the system busy-hour periods is worst case, and it not included in this testing. (When the system is busiest, the system is stressed the most and can cause quality indexes to increase above target thresholds sooner, since they are closer to the thresholds during the busy hour periods. For example, any outside interference during busy hours periods can cause an increased likelihood of TDMA Calls increasing above the 1% Bit Error Rate level, and CDMA calls increasing mobile transit power and dropping calls.)

Measurements will be conducted throughout the terrestrial cell site's coverage area, which include forward and reverse link performance metrics, while steady-state AirCell equivalent signal levels are injected into the receive path. This will be compared with the performance of the cell when no AirCell signals are introduced. Analysis of the Phase 2 test results will focus on cell site reverse-link (terrestrial mobile RX to cell site TX) performance metrics. The terrestrial cell site reverse link would be the affected link from an AirCell equipped airplane flying within range of the terrestrial cell site.

The Phase 2 test descriptions, procedures, and system performance metrics are described below.

<u>Phase 2 Test Description & Procedures:</u>
Phase 2 involves measuring the impact to cell site performance when AirCell signal levels are injected into the CDMA, TDMA and AMPS cell sites, in separate tests. Drive test measurements will be conducted throughout the cell coverage area measuring forward and reverse link performance metrics. This will be compared to the performance of the terrestrial cell site under normal operating conditions, when no AirCell signals are injected.

The drive route covers an even distribution of roads within the Ewingville cell site coverage area for its gamma sector, and is representative of the locations and signal levels of the cellular customers in this area. To verify this, pre-testing was performed to measure the cell site received signal distributions from normal customer calls, over a 24-hour period, for a typical business day. These customer signal levels were measured with the Lucent's Power Level Measurement (PLM) function, which measures the cell site received signal levels for active calls over a period of time, using the cell site receiver. Then, pre-testing was performed to establish that the signal levels from the drive route match the signal levels from normal cellular customers. Drive tests utilized a 1992 Plymouth Voyager, Comarco drive test equipment, cellular phone equipment, and mobile antenna used inside the test vehicle. The resulting signal levels from the drive route matched the customer signal levels, as provided by an exhibit in the compatibility test report.

The drive route signal levels were measured with the Lucent RF Trace function, which measures the cell site received signal levels for the drive test phone, using the cell site receiver. This procedure it established that the drive route was representative of normal signal levels from actual customer calls. The same drive route was used for both A & B-band systems, and for AMPS, TDMA and CDMA technology tests. Therefore, test results can be directly compared for all technologies.

Once the drive route was established, a baseline drive test was completed with no AirCell signals injected. This served as our performance baseline of the terrestrial cell site under normal operating conditions, when no AirCell signals were injected. The results of phase 2 tests with AirCell signals injected, are then able to be compared to the performance of the baseline test.

Using calibrated signal generators, equivalent AirCell signal levels are injected into the cell site receive path at the -50 dB coupler port, using an offset to reference the cell site hatch plate. This is the 1st directional coupler in the receive path of the cell site, and is within the Lucent Series 2 Cell Site Antenna Interface Frame (AIF). The signal levels are equally fed to both diversity receive paths with a cable splitter. The insertion loss of the test coaxial cables and splitters used in the testing, and the offset to the cell site receive path connection point, are measured with calibrated test equipment and recorded. All signal levels in the engineering report will be referenced to the input of the cell site (hatch plate reference). In Phase 2 tests, simulating actual AirCell signals, the calibrated signal generators injected an audio tone modulated carrier. In all Phase 2 tests, the signal generator used an audio tone modulated carrier representing a voice conversation, using a 1 kHz frequency at 2.9 kHz deviation. In some Phase 2 tests, equipment functionality permitting, the generator used two tones, the first to represent the voice conversation, and the second to represent the AMPS SAT at 6 kHz frequency, 2 kHz deviation.[1]

Pictures 2.2-A Phase 2 Test - Signal generator connected to the TDMA cell site

The injected signal level remains at a fixed steady-state for the duration of each drive test. After a baseline drive test with no injected signal levels, the signal generator begins the first test at –126 dBm (referenced to the cell site hatch plate), and increases by 3 dB for each subsequent drive test. This process is repeated until the highest AirCell signal level measured in Phase 1 tests (-72 dbm) is used for Phase 2 injection testing. This test method allows the impact to the performance of the terrestrial cellular system to be measured for each injected signal level in separate tests. This is repeated for each wireless technology included in Phase 2 tests.

During the Phase 2 injected interference tests, measurements are made at the cell site and test mobile phone and the cell site forward and reverse link performance are recorded for each drive test. These results are analyzed and compared, to assess the impact to the performance of the terrestrial cell site.

[1] Some of the signal generators used in Phase 2 testing were not capable of modulating two tones. In these cases, only a single 1 kHz tone was used. A single tone modulated carrier was used in all AMPS technology Phase 2 tests. Two tones were used in all TDMA technology tests. In CDMA technology tests, a single tone was used at the Ewingville site, and two tones were used at the Trenton site. In a separate analysis, additional tests were performed for AMPS & TDMA technologies comparing the tone modulated test results, to the results of tests with modulated ‘harvard sentence’ conversations and SAT. In comparison of these two tests, the results are equivalent. And, therefore, the test scenario in this test plan, using single and two tone modulation carriers, are acceptable simulations for AirCell calls.

Comarco Baseline drive test equipment was utilized. It is capable of measuring both forward and reverse link quality measurements and call statistics, as listed in each technology section below. It is configured to execute automated and continuous calling routines, which will be used to make calls over the entire drive route. The calling routine will use the call duration of 2½ minutes. The drive test procedures and measurements for each wireless technology, are listed in the sections below. The Comarco equipment collected the cell site forward link RF and performance data for the drive routes. For more information on the Comarco Baseline measurements refer to section 2.2.4.

Lucent RF Call Trace measurements collected reverse link RF and performance data. In the post-processing of Phase 2 test data, the reverse link RF Call Trace data was correlated to the forward link drive test data using the time stamp field. Power Level Measurements, Switch Statistics and digital audio recordings were also collected on the reverse link to supplement the collected test data. For more information on the RF Call Trace measurements refer to section 2.2.4.

The Phase 2 AMPS tests occurred in market between 11/1/01 and 1/15/02. The Phase 2 TDMA tests occurred in market between 12/27/01 and 1/15/02. The Phase 2 CDMA tests occurred in market between 1/25/02 and 3/2/02. The Phase 2 tests were coordinated with the cellular carrier's field operation personnel for the access to the cell sites.

The following sections of the Test Plan describe the Phase 2 tests for the respective wireless technology tests, included in the test plan. The CDMA tests are performed within Verizon's B-Band cellular network, the TDMA tests are performed within Cingular's A-Band cellular network, and the AMPS tests are performed within Verizon's B-Band cellular network.

2.2.1 TEST 2A - Impact to CDMA Voice Technology (IS-95)

For CDMA voice technology tests, the AirCell equivalent signals levels are injected on the CDMA channel carrier, which is used by the test mobile for its voice and overhead control signals during the drive tests. The cell site was configured and operating in its normal mode, with its CDMA carrier shared by all customers that attempt to acquire it based on the normal cell site hashing algorithms used for system load balancing between multiple CDMA carriers in service. The cell site's hashing algorithm uses the mobile's ID number to assign a default CDMA carrier for service. The default CDMA carrier for the test mobile was the 1st CDMA carrier in the band, and the signal generators injected signals only on this CDMA carrier. In this test method the cell site is operating normally, with actual cell site loading conditions present from actual cellular customers sharing the same CDMA carrier with the test mobile. Also present are actual noise levels from other mobiles served by the surrounding cell sites. In Phase 2 CDMA tests, the cell site is performing and operating in its normal mode with all of its antennas connected and configured normally.

To prevent unwanted interference to Verizon's customers in the busiest hours of the day, the system busy hours were not included in the testing. The Phase 2 CDMA drive testing occurred during the time periods of 9:00 am to 2:00 pm on normal business days. These time periods represent normal cell site operating day-time noise floor conditions that exist from actual nearby cellular CDMA users. No changes were made to the test cell site or the surrounding cell sites. The Ewingville test cell site and surrounding cells sites were operating, configured, and serving customers in their normal mode. The operating cell site noise floor levels were measured for the test cell site using the procedure below.

The Phase 2 CDMA drive tests used the following injected signals, in separate tests:

1. Signal generator injected 1 signal within the CDMA carrier, at the center 30 kHz channel.
2. Signal generator injected 2 signals within the CDMA carrier; the 1st at the center 30 kHz channel, and the 2nd at 10 channels above the center channel.
3. Signal generator injected 1 signal within the CDMA guard band channels, at the 1st adjacent 30 kHz channel within the CDMA guard band channels
4. Signal generator injected 2 signals within the CDMA guard band channels, at the 1st and 4th adjacent 30 kHz channels within the CDMA guard band channels

Since CDMA systems utilize a frequency reuse network configuration of N=1/3 (using the same CDMA channel in all 3 sectors of every cell site), it is very likely that the AirCell airborne signals will be received on multiple sectors & sites in the same area. During the drive route for this area, the CDMA phone is in soft handoff regions most of the time. For this reason, the Phase 2 CDMA tests involved injecting signals, at the same signal level, on 3 sectors of the 6 sectors that serve the test mobile on the drive route, while it is in soft handoff. Depending on the location of the drive test vehicle within the drive route, the CDMA phone is soft-handoff with up to 6 different sectors. (For the drive route, the percent of time the test calls are in soft hand off are 38%, 23%, 15%, 4%, and 1% for 2-way, 3-way, 4-way, 5-way, and 6-way soft handoff; or a total of 81% of the time in soft handoff.) The six sectors that serve the test mobile on the drive route are: the gamma and beta sectors of the Ewingville cell site, the alpha sector of the Trenton cell site, the alpha and beta sectors of the Ewing Township cell site, and the beta sector of the Pennington cell site. These cell sites are depicted in the map above, entitled Phase 2 Test Area and Surrounding Cell Sites. In Phase 2 tests, three sectors were used in the testing with signals injected into their receive paths at equivalent levels; they are the gamma and beta sectors of the Ewingville cell site, and the alpha sector of the Trenton cell site. The scenario used for Phase 2 CDMA tests is likely to occur with an airplane flying between the Ewingville and Trenton cell sites. In this scenario, the airplane would be oriented south of the Ewingville cell site, and north of the Trenton cell site. The soft handoff and all other cell site configurations and parameters were operating and performing normally.

Drive test measurements and Lucent RF Call Trace measurements are used to collect reverse link cell site performance data. The measurements for the reverse link RF Call Trace data were correlated to the forward link drive test data using the time stamp values.

First, a baseline test with NO AirCell signals was performed for the established drive route. Then, the tests with AirCell equivalent signal levels injected into the cell receive path, were performed for the same drive route. During these tests, the cell site operating noise floor was the actual noise floor which exists in market during normal business day time periods. The system busy-hour time periods are excluded from these Phase 2 CDMA tests, to avoid interfering with CDMA cellular service during its busiest times. The following terrestrial cellular performance metrics are recorded for each drive test.

<u>Phase 2 CDMA Tests – Cellular Performance Metrics:</u>

1. Quality of Service (Call Statistics) – Dropped Calls, Failed Access Attempts, Total Calls, Total Access Attempts, Overloaded Calls to other CDMA Carriers and to AMPS System. These results are provided for each drive test.
2. Voice Quality - Reverse Link Mean Opinion Score (MOS). The results will show the average audio quality MOS for each drive test.
3. RF Performance Metrics - Cell Site Received Signal Levels, Mobile Transmit Power levels, CDMA Carrier Frequency, Walsh channel, Transmit Digital Gain, forward and reverse FER, forward pilot Ec/Io, and reverse Eb/No, PN offset, Timeslot, GPS and Time Stamp. These metrics allow us to compute the average Frame Error Rate (FER) and received Bit Energy per Noise (Eb/No) ratio level at the cell site, and the mobile transmit power for each drive route.
4. Capacity – To assess the capacity loss to the CDMA system, two results are provided:
   A. The total minutes of use on a CDMA voice channel for each drive route will be computed, and compared to the baseline results with no injected signals.
   B. Additional Capacity Tests with the number of supported calls are provided for each injection level test. This capacity test is described below.
5. Digital Audio Recordings for the reverse link, from the landline phone.

<u>ADDITIONAL PHASE 2 CDMA TESTS USING THE DRIVE ROUTE:</u>

In addition to the Phase 2 CDMA drive tests described above, the following additional CDMA tests were completed. The following tests and measurements are performed using other system configurations, as described below.

<u>CDMA Drive Tests at 3 dB System Loading</u>

To capture the affects to a “3 dB loaded” CDMA system, additional drive tests were performed off-hours with a cleared CDMA channel, using a dual-circulator and 3 dB pad in-line with the mobile test antenna. For this test, one CDMA carrier was cleared and isolated for use with our test mobile phone only, by using the Lucent Test Carrier feature and OCNS for forward link loading. This is a common industry procedure for simulating typical CDMA system-loaded conditions for cell site testing. This test condition does not simulate worst-case CDMA system loading. It only simulates a typical system loading condition that corresponds to a reverse-link noise rise of 3 dB. The Phase 2 CDMA test results for this simulated system-loaded condition are referred to as “3 dB loading” in the test report. In these CDMA tests, the cell site is operating and performing normally with all of its cell parameters, soft hand settings, and antennas connected and configured as normal, with one exception. This exception is that the cell site is in Test Carrier mode, as defined above. In these tests, the signal generator injected only 1 signal within the CDMA carrier, at the center 30 kHz channel. The results from the "3 dB loading" drive tests were compared to the results from the drive tests under normal day-time loading conditions (from the actual customers present in market).

ADDITIONAL PHASE 2 CDMA TESTS AT FIXED, STATIONARY LOCATIONS:

In addition to the Phase 2 drive tests above, the following three stationary tests (Stationary Test A, B & C) were performed at fixed locations within the test site's sector coverage area, in off-hour time periods, with a cleared CDMA channel, under different loading conditions as described below.

CDMA Capacity Tests With A Stationary Vehicle (Stationary Test A & B)

The first and second stationary test is the CDMA Capacity Tests with a stationary vehicle at fixed locations. For these tests, the test vehicle was parked at fixed locations; 1.) close to the Ewingville cell site, about 0.3 miles away; and 2.) at the edge of the Ewingville cell site's gamma sector coverage area, about 1.5 miles away. For this test, the CDMA system loading condition was created, by clearing a CDMA carrier with Lucent Test Carrier mode, and placing multiple test calls on the cell site using the Comarco and MCS4 test units phones. For these tests, the circulator and 3 dB pad was not used. The system load was being established by the multiple calls made by the Comarco and MCS4 test units at the fixed stationary location. In these CDMA tests, the cell site is operating and performing normally with all of its cell parameters, soft hand settings, and antennas connected and configured as normal, with one exception. This exception is the Test Carrier mode, which was used isolate a CDMA carrier for use with the test mobiles.

At the first location the mobile was not in a soft handoff region, and at the second location the mobile was in a soft handoff region. For these tests, the signal generator injected signals into the Ewingville beta and gamma sectors, and the Trenton alpha sector. For this test, the Comarco baseline and MCS4 test equipment was configured to maintain calls for the duration of each test, and called a landline connection with audio from a radio station on the cell forward link and no audio on the reverse link. For these tests, four separate tests were performed with the signal generator injecting signals on the same 30 kHz channels, as specified in the Phase 2 drive tests above. For these tests, the signal generator injected a fixed steady-state signal level at –126 dBm for a period of approximately 3 minutes, than increased its signal output level by 3 dB, for each subsequent 3 minute period. The test mobile phone's transmit power level and the number of calls supported at this location were recorded for the entire test. In the post-processing of the test data, the average mobile phone transmit power and number of supported calls for each 3 minute period is provided. The results of these capacity tests show the loss in capacity of the CDMA test cell site to serve multiple calls, for each injected signal level.

CDMA Capacity Tests With A Stationary Vehicle, With No Soft Handoff (Stationary Test C)

The third stationary test is the CDMA Capacity Tests with a stationary vehicle at the cell edge with no soft handoff. For these tests, the test vehicle was parked at a fixed location at the edge of the Ewingville cell site's gamma sector coverage area, about 1.5 miles from the site. This third stationary test is performed after the second stationary test is completed. It repeats the same exact test as the prior stationary test, with one exception. This exception is that the surrounding

CDMA cell sites have their CDMA carriers turned off. This forces the test mobile to only use the test site's gamma sector pilot for its active soft handoff list. The purpose of this test is to simulate the affects of an in-building user that is 1.5 miles from a suburban cell site, and is not in a soft-hand off region. In many cases, in-building cellular users cannot benefit from affects of soft handoff since their signals are very directional through widows toward its serving cell site. This also simulates a CDMA cell site with a "no soft handoff" region that extends to 1.5 miles away from a cell site, which is common for rural cell sites. All other cell site settings are operating and performing normally with antennas connected and configured as normal. The results of these capacity tests show the loss in capacity of the CDMA test cell site to serve multiple calls in a "no soft handoff" region that is 1.5 miles from the cell site, for each injected signal level.

The CDMA Capacity tests were accomplished by utilizing the MCS4 CDMA field test unit capable of multi-phone operation, which can establish up to 22 simultaneous calls. For more information on the MCS4 field test unit refer to section 2.2.4.

2.2.2 TEST 2B - Impact to TDMA Voice Technology (IS-136)

For TDMA voice technology tests, the AirCell equivalent signals levels are injected on a TDMA channel, containing two TDMA voice timeslots and one digital control timeslots. In Phase 2 TDMA tests, a TDMA radio channel in the gamma sector was isolated for our test mobile only, with the Lucent PSID feature, to prevent other cellular customers from acquiring the channel which has the injected equivalent AirCell signal levels. This was necessary to prevent unwanted interference to Cingular's TDMA customers, being served by this sector, while Phase 2 TDMA tests are performed on this sector. In the Phase 2 TDMA tests, the cell site is operating and performing normally with all of its cell parameters, and antennas connected and configured as normal, with only one exception. The one exception is cell site PSID Feature, which does not affect the performance of the cell site, but only has the affect of assigning the test mobile to the voice channel which has the signal injections on it. This feature was necessary since V-COMM tested with a "live cellular system" and did not wish to cause interference to Cingular Wireless' customers during the day-time testing period. The TDMA radio channel 240 is in the test cell site's gamma sector, and was used by the test mobiles and signal generator. The TDMA radio channel 240 was selected from one of the TDMA channels that existed in the gamma sector's assigned frequencies, which was part of Cingular's frequency plan of channels for this sector. The TDMA radio channel 240 is used in Phase 2 TDMA tests, and had a digital control channel in timeslot 0, and 2 digital voice channels in the other 2 timeslots. The injected signals occur on this TDMA channel during Phase 2 TDMA tests.

Drive test measurements and Lucent RF Call Trace measurements was used to collect reverse link cell site performance data. The measurements for the reverse link RF Call Trace data were correlated to the forward link drive test data using the time stamp values.

Phase 2 TDMA technology tests occur during normal business day time-periods to represent normal cell site operating noise floor conditions that exist from other nearby co-channel cellular users. No changes were made to the cell site or the frequency plan of the surrounding TDMA cell sites which would affect the performance of the cellular system. The Ewingville test cell site and surrounding cells sites were operating, configured, and serving customers in their normal mode. The TDMA operating noise floor level was also measured for the test cell site using the procedure below.

First, a baseline test with NO AirCell signals was performed for the established drive route. Then, the tests with AirCell equivalent signal levels injected into the cell receive path, were performed for the same drive route. During these tests, the cell site operating noise floor was the actual noise floor which existed in market during normal business day time periods. The system busy-hour time periods are excluded from these Phase 2 TDMA tests, to avoid interfering with TDMA cellular service during its busiest times. The following terrestrial cellular performance metrics were recorded for each drive test.

<u>Phase 2 TDMA Tests – Cellular Performance Metrics:</u>

1. Quality of Service (Call Statistics) – Dropped Calls, Failed Access Attempts, Total Calls, Total Access Attempts. These results are provided for each drive test.
2. Voice Quality - Reverse Link Mean Opinion Score (MOS). The results will show the average audio quality MOS for each drive test.
3. RF Performance Metrics - Cell Site Received Signal Levels, Mobile Transmit Power levels, BER, channel, Timeslot, GPS and Time Stamp. These metrics allow us to compute the average received signal level at the cell site, the average reverse link BER, and the TDMA carrier to interference (C/I) ratio for the each drive route for comparisons.

4. Capacity – To assess the capacity loss to the TDMA system, the total minutes of use on a voice channel for each drive route will be computed, and compared to the baseline results with no injected signals.
5. Digital Audio Recordings for the reverse link, from the landline phone.

TDMA Cell Site Operating Noise Floor Measurements:
Prior to drive testing, the cell site operating noise floor level for TDMA systems is measured over a 24-hour period with the Lucent Power Level Measurement (PLM) function, which measures the received signal levels on idle TDMA voice radio channels. These PLM measurements will be provided with the Phase 2 TDMA results. The TDMA PLM data for the Ewingville test cell site exhibits a 50% median operating noise floor of –127 dBm, over the 24-hour period.

2.2.3 TEST 2C - Impact to AMPS Voice Technology (IS-553)

For AMPS voice technology tests, the AirCell equivalent signals levels were injected on the AMPS voice channels used by the drive test mobile phone. The signals are not injected on the AMPS control channels, during these tests. Drive test measurements and Lucent RF Call Trace measurements are used to collect reverse link cell site performance data. The measurements for the reverse link RF Call Trace data were correlated to the forward link drive test data using the time stamp values.

The Phase 2 AMPS technology tests occurred during normal business day time-periods to represent normal cell site operating noise floor conditions that exist from other nearby co-channel cellular users. No changes were made to the cell site or the frequency plan of the surrounding AMPS cell sites. The Ewingville test cell site and surrounding cells sites are operating, configured, and serving customers in their normal mode. The AMPS operating noise floor level was also measured for the test cell site using the procedure below.

In Phase 2 AMPS tests, the signal generator modulated a single tone to represent the voice conversations of an AirCell call, with a tone at 1 kHz frequency, 2.9 kHz deviation. For these tests, the injected signal did not modulate the AMPS SAT tone.

First, a baseline test with NO AirCell signals was performed for the established drive route. Then, the tests with AirCell equivalent signal levels injected into the cell receive path, were performed for the same drive route. During these tests, the cell site operating noise floor was the actual noise floor which exists in market during normal business day time periods. The system busy-hour time periods are excluded from these Phase 2 AMPS tests, to avoid interfering with AMPS cellular service during its busiest times. The following terrestrial cellular performance metrics were recorded for each drive test.

<u>Phase 2 AMPS Tests – Cellular Performance Metrics:</u>

1. Quality of Service (Call Statistics) – Dropped Calls, Failed Access Attempts, Total Calls, Total Access Attempts. These results are provided for each drive test.
2. Voice Quality - Reverse Link Mean Opinion Score (MOS). The results will show the average audio quality MOS for each drive test.
3. RF Performance Metrics - Cell Site Received Signal Levels, Mobile Transmit Power levels, channel, SAT, GPS and Time Stamp. These metrics allow us to compute the average received signal level at the cell site, as well as the AMPS carrier to interference (C/I) ratio for each drive route for comparisons.
4. Capacity – To assess the capacity loss to the AMPS system, the total minutes of use on a voice channel for each drive route will be computed, and compared to the baseline results with no injected signals.
5. Digital Audio Recordings for the reverse link, from the landline phone.

<u>AMPS Cell Site Operating Noise Floor Measurements:</u>

Prior to drive testing, the cell site operating noise floor level for AMPS systems was measured over a 24-hour period with the Lucent Power Level Measurement (PLM) function, which measures the received signal levels on idle AMPS voice radio channels. These PLM measurements are provided with the Phase 2 AMPS results. The AMPS PLM data for the Ewingville test cell site exhibits a 50% median operating noise floor of –127 dBm, over the 24-hour period.

2.2.4 Test Equipment and Measurements

The following test equipment & tools, measurements and procedures were used in the Phase 2 signal injection tests.

Phase 2 Test Equipment & Tools:

Signal Generator, Comarco drive test unit, Lucent Power Level Measurements (PLM) and RF Call Trace, Spectrum Analyzer with filter and low noise figure LNA, Miscellaneous test cables, connectors, hardware, and MCS4 multi-phone test unit.

The Phase 2 Test Equipment and Tools are described in more detail below.

Comarco Drive Test Tool:

Comarco field measurement tool was used to measure forward link (cell site TX to mobile phone RX radio link) system performance parameters. When combined with the LAMS unit (described below), it also provides the MOS (Mean Opinion Audio Quality) for the reverse link (mobile phone/TX to cell site RX radio link) system quality value. The combined data outputs from the Comarco test unit and LAMS computer are used for the Phase 2 drive tests. The Comarco unit contains 3 phones, which are TDMA (A-band), AMPS (B-band)), and CDMA (B-band) technology phones. These Comarco phones measure and record forward link RF data parameters, such as Channel Number, Channel Type, Ec/Io, SAT, VMAC, Time Slot, GPS latitude and longitude, as well as reverse link MOS (LMOS) values for their respective technologies. For CDMA technology there were two additional Comarco output data files used for analysis, A4 for the CDMA active pilot parameters, and P4 for the CDMA pilot power parameters. Additionally, for all technologies there was an AllStats file created by Comarco which provides call statistics, such as, dropped and blocked call numbers and percentages, total number of call attempts, number of successful calls, etc. for the each drive test performed. The Comarco and LAMS systems use industry accepted "hardvard sentences", for audio conversations between the mobile phone and landline system, as described below. Comarco data is recorded with a measurement interval of one second.

Comarco Landline Tool (LAMS) – Used to Measure Audio Quality (MOS):

The LAMS (Landline Audio Measurement Station) is a computer station that is used in conjunction with the Comarco field measurement unit, to receive a call on a standard plain old landline telephone (POTS line). The LAMS is an audio monitoring system used to monitor forward and reverse link audio quality Mean Opinion Score (MOS) values. MOS is an audio quality performance metric that provides a measurement in terms of overall quality, listening efforts, intelligibility, and naturalness. It uses the industry standard "North American English Harvard phonetically balanced sentence pairs with two male and two female speakers." Each sentence pair is approximately 7 seconds in duration.

The MOS measurement process is as follows. A test call is placed between the Comarco mobile unit and the landline unit (LAMS). A complete forward/reverse link sequence takes about 30 seconds; therefore, the system makes about four MOS measurements per minute, two forward links and two reverse links. The forward/reverse link process continues until the call duration is reached or until the call is dropped.

Based on extensive testing by Comarco Technologies and laboratory testing by AT&T Voice Quality Assessment Laboratory in New Jersey the following are suggested MOS ranges:

5.00 – 3.75 Excellent – Perfect Quality
3.75 – 3.25 Good Quality
3.25 – 2.75 Fair Quality
2.75 – 2.25 Poor Quality
2.25 – 1.00 Bad Quality

Although 5.0 is indicated as the maximum MOS value, 4.36 is the maximum value used by LAMS test system.

Algorithms modeling the human hearing system determine the MOS values. Electronic filters are shaped to represent the human hearing ability in the telecommunications frequency ranges. The key areas are bandwidth, noise, distortion, and erasures or gaps in the speech. The MOS algorithm is a large number of mathematical expressions that represent the above impairments and their interaction. The resultant MOS value is to be representative an objective assessment of the audio quality, and equivalent to the results of a mean opinion survey of over 1,000 people. Comarco MOS data is recorded with a measurement interval of approximately 20 seconds.

<u>RF Call Trace</u>

Lucent's RF Call Trace function was used to collect the reverse link (mobile phone to cell site radio link) system performance parameters and signal quality. These measurements are performed by the cell site radio and recorded at the switch when the voice channels are active. Reverse link system parameters such as the Channel number, Frame Error Rate (FER), Bit Error Rate (BER), Ec/Io, Eb/No, Cell Site ID, Sector ID, signal strength, etc. corresponding with their respective technologies AMPS, TDMA, and CDMA.

The RF Call Trace files from the switch are recorded with time stamp, and are merged in post-processing routines with the Comarco data. These files provide both forward and reverse link system performance metrics for the drive tests. RF Call Trace data is recorded with a measurement interval of two seconds.

<u>MCS4 - CDMA Multiple Phone Test Unit – used for CDMA Stationary Capacity Tests Only</u>

Mobile Call Simulator–IV (MCS4) is manufactured by Neopoint and utilizes up to 22 CDMA (IS-95) Qualcomm QCP 820 handset phones (13 kb vocoder) with current hardware options. The unit is capable of simultaneously making 22 calls (with 22 test cables) and keeping them up for the duration of each Phase 2 CDMA tests. It can consistently monitor and maintain 22 phone calls. For example, if there are any dropped calls, it would bring the call back up automatically after a pre-set idle time. The idea is to load the cell sites within the pre-determined test area, and keep it loaded to represent normal CDMA system loaded conditions for a single CDMA carrier. The equipment was used in a stationary test vehicle at a pre-determined location. The unit uses audio tones for forward and reverse link paths to simulate voice conversations.

<u>Spectrum Analyzer</u>

A calibrated spectrum analyzer, HP model 8591 EM Spectrum Analyzer, was used in the Phase 2 testing for a variety of purposes, including measuring & verifying signals, power levels, receive path offsets, insertion loss, and other functions. It has a frequency range of 9 kHz To 1.8 GHz, from -130 to +30 dBm, with 30 Hz to 3 MHz resolution bandwidth. Frequency accuracy, up to 1 GHz, is +/- 240 Hz. The overall signal accuracy is approximately +/- 1 dB, after a 30 minute warm up period. The unit's signal accuracy was checked and verified with other calibrated test equipment prior to testing in the field.

Signal Generators

Calibrated signal generators, IFR model 2026 and other equivalent models, were used in the Phase 2 testing to simulate the interfering AirCell signal, and inject steady-state levels into the terrestrial cell site receive path. The injected signal was a modulated carrier, as specified in Phase 2 tests above. In addition, it was used to measure & verify signals, power levels, receive path offsets, insertion loss, and other functions. This signal generator's frequency range is 10 kHz to 2.4 GHz. The signal generator is capable of 1 or 2 signal outputs, through separate or combined output ports. Each signal source can be controlled independently in frequency and level and each has its own amplitude, frequency, phase, FSK and pulse modulation capability. Each source is also capable of two separate internal generated audio tones and external modulation. RF output accuracy of this instrument is +/- 0.8 dB from 30 kHz To 1.2 GHz. The unit's signal and frequency accuracy was checked and verified with other calibrated test equipment prior to testing in the field.

Phase 2 Test Procedures & Test Notes:

1. All test equipment accuracy, operation and specifications were reviewed and verified prior to testing, on frequencies within the cellular band and utilized in testing.
2. GPS and cellular mobile antenna are used with the Comarco drive test equipment inside the drive test vehicle.
3. The Comarco drive test equipment was configured for automated and continuous calling routines during drive tests, using the industry standard "hardvard sentences" for two way audio conversations representing approximately 40% voice activity in each direction (forward & reverse-links). The duration of each call was configured to 2 minutes. If a call is dropped or blocked, the equipment waits a short period of time and attempts the call again.
4. The time stamp field is used to merge the forward-link drive test measurements with the reverse-link RF Trace measurements. The time of each device was synchronized with GPS time at the beginning of each test day. This merged data has a resolution of 2 seconds.
5. The insertion loss of the test coaxial cables used in testing, and the offset to the cell site receive path connection point, were measured with calibrated test equipment and recorded.
6. All signal levels in the report are referenced to the input of the cell site (hatch plate reference). This reference is the antenna side connector, of the cell site jumper cable used to connect the cell site equipment to the transmission line. All signal power units are in dBm (decibels, ref. to 1 milliwatt).

Phase 2 Tests - System Performance Metrics

For the purposes of evaluating the performance impact to the terrestrial test cell site, several metrics were evaluated. Some metrics are applicable to all three technologies, while others are technology specific. Some metrics correspond to the quality of service of the calls made, and others correspond to the reverse-link cell site performance metrics. The terrestrial cellular performance metrics considered in Phase 2 testing are as follows:

- Blocked and Dropped Calls
  - These are the calls that are dropped from the system, and the attempted calls that are blocked. These are quality of service metrics.
- Digital Errors Rates

- This metric is the bit error rate percent (ie. BER%) that is measured for the cell reverse-link (mobile Tx to cell Rx).

- Mean Opinion Audio Quality Score (MOS)
  - This metric is the Mean Opinion Score of the audio quality measured for the cell reverse-link. The Comarco drive test equipment modulates specific audio conversations (Harvard Sentences) to replicate natural speaking voice for objective assessment of the audio quality. A MOS value greater than 3.25 is considered “good” quality, and below this is considered “fair” quality. A MOS value below 2.75 is considered “poor” quality, and a MOS value below 2.25 is considered “bad” quality.
- Mobile Transmit Power
  - This metric is the Mobile Transmit Power for the reverse-link.
- Call Overflow
  - This metric is for CDMA systems, and shows the percent of established calls that are overflowed to either other CDMA carriers, or analog (AMPS) voice channels.
- Capacity
  - This metric represents the percent loss in traffic served for terrestrial test cell site.
- Minutes of Use (MOU)
  - This metric represents the Minutes of Use on a voice channel, for the drive test.
- Carrier to Interference Ratio (C/I)
  - This metric is the ratio of cell site received signal level vs. the interference plus noise level, for the cell site reverse link.
- Bit Energy per Noise (Eb/No)
  - This CDMA metric is the ratio of energy of the call signal level vs. the noise level, for the cell site reverse-link.

Performance Metrics: Digital Error Rates are TDMA and CDMA specific, Call Overflow is CDMA specific, Carrier to Interference (C/I) is TDMA and AMPS specific, and Eb/No is for CDMA. All metrics are provided for the entire drive route.

3.0 TEST MARKET LOCATION & TEST ISSUES

3.1 TEST MARKET LOCATION

The test market location is within the Philadelphia, New Jersey and New York market areas within range of the AirCell Marlboro cell site located in the central part of New Jersey. For the Phase 1 flight tests, the serving AirCell cell site is the Marlboro, NJ cell site. The B-Band operator is Verizon Wireless and the A-Band operator is Cingular Wireless in this region. The A-Band operator currently utilizes AMPS and TDMA technology, while the B-Band operator currently utilizes AMPS, CDPD and CDMA technology. A typical and representative suburban cell site for the A-Band and B-Band systems is utilized for Phase 2 interference tests.

Drive routes were specified within the designated cell coverage areas in phase 2 tests. Aircraft flight routes and flight plans were reviewed with the aviation pilots and FAA airspace control centers in phase 1 tests. V-COMM conducted project management and coordinated project testing activities with participation from the cellular operating companies, aircraft pilots, FAA, and regional airspace control centers. AirCell agreed to certify that the AirCell cell site and AirCell mobile phones utilized in the testing were representative and operating according to AirCell specifications.

3.2 EQUIPMENT CALIBRATION

All equipment utilized in the testing was checked and verified for proper operation and calibration according to manufacturer specifications. All measurement tools, phones, ancillary test equipment, and test methods were reviewed, measured and verified to meet operating specifications and to allow the test results to be conclusive.

3.3 PRE-TESTING ISSUES

Due to the complexity of the testing, some pre-testing was required to verify the integrity of the test equipment, methods and procedures, prior to actual testing occurring in market. This was an important step to determine if any modifications in test procedures were necessary to achieve test objectives. This was critical to ensure accurate and conclusive test results.

3.4 FUTURE TESTING

This test plan did not include phase 2 interference tests with new emerging wireless technologies, including:
E911 Phase II Network-based Location Technologies, TDMA Circuit-Switched Data (IS-130/135), Enhanced Data Rates for GPRS Evolution (EDGE), Global Solutions for Mobile Communications (GSM) Voice Technology, CDMA2000 Voice & Packet Data Technologies (3G-1xRTT and 3G-1xEVDO at 1.25 MHz, and 3G-3X at 5 MHz) and UMTS Wide-band CDMA technologies.

In addition, this test plan did not include phase 2 interference tests with some existing and other wireless technologies, i.e. CDPD, NAMPS, and tower-top LNA sites. Also, it does not include phase 2 interference tests for cell sites in Dense Urban, Urban, Rural or Quiet Rural market environments. This Test Plan utilizes a typical cell site in a suburban market environment.

To assess the impact to other wireless technologies, applications and environments that not included in this Test Plan, future testing and analyses are required.